GEOGRAPHIC INFORMATION SYSTEMS AS A VESSEL FOR CONVENTIONAL AND ALTERNATIVE FORMS OF ZONING

JOSEPH KITCHING

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Supervisor: Dr G. Musvoto Date: 06 October 2020

ABSTRACT

Given the well-documented rates of global urbanisation and the fact that sub-Saharan Africa is set to urbanise at the highest rate during the next few decades, it is easy to understand that urban management systems will increasingly be under pressure to operate efficiently, effectively and transparently in order to circumvent potential economic, social and environmental disasters.

A land-use management system is one of the management systems in urban areas aimed at ensuring health and safety, environmental quality, sustainability, social equity, and amenity, amongst others. Since the beginning of the twentieth-century, a key tool of planners wishing to accomplish this, has been zoning. Although zoning has been abused, and heavily criticised for that, the objectives of zoning systems around the world echo noble values such as promoting environments that are safe from flooding and fire hazards, that encourage harmonious communities and economic growth, that preserve agricultural land, and protect the natural environment. Conventional zoning, which was significantly shaped by the US Supreme court's village of Euclid decision, focuses on the separation of incongruent land uses. There are also several other types of zoning such a flexible Euclidean zoning, performance-based zoning and even no zoning. Amongst the novel types are form-based codes, which stem from the New Urbanism paradigm. Form-based codes focus more on the public realm and the appearance of spaces and structures rather than the use of space. Practically and problematically, both conventional and alternative zoning schemes are currently comprised of a map and a separate text document. The map depicts the geographic dispersion of zones, typically related to properties or zoning districts. The text document contains regulations pertaining to the various zones, procedures and definitions. Alongside the inefficient separation of regulation and map, are the variations within single zones where specific, locally important, regulations apply to some properties within the zone.

Geographic information systems (GIS) have been evolving since the mid-twentieth century and have gained serious traction with the advent of the microcomputer. Defined by many as a system that captures, collects, manages, analyses and presents

geographic data and attributes, it is essentially a database linked to a geographic component, In the case of zoning, it currently comprises geographic properties linked to attributes describing the zoning. The rigid, surveyed, property boundaries make the vector or discrete objects model ideal for the representation of zoning. The raster model – the other half of the debate – is useful in representing images supporting the regulations.

Given the need for more efficient systems, the pervasiveness of corruption and poor capacity in municipal systems, the omni-present abuse of power, the need for an informed citizenry and laws that are comprehensible, this study aims to see if GIS can be used to represent the regulations in conventional and alternative schemes. To establish this, six sample cities from around the world, more than twenty conventional zones in the eThekwini municipality and two zones from the Daufuskie form-based code were assessed to determine what types of regulations are common and whether they could be represented as either geographic norms or attributes to geographic features.

This study found that GIS is able to represent all regulations in conventional schemes and most of the regulations in alternative zoning. It also found that some regulations are naturally inclined to spatial representation, others as attributes, and still others as scanned attachments or hyperlinks. This implies that there is no need for the separation of regulations from property and the confusion and potential misinterpretation that are associated with current practices.

Keywords: Geographic Information Systems (GIS), Planning, Euclidean zoning, Form based codes

DECLARATION

I declare that unless otherwise acknowledged in the text, this thesis is my own original unaided work, and has not been submitted in whole or part, to any other university.

Joseph Kitching

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List of acronyms and abbreviations

BLOB:	Binary large object
CADD:	Computer aided draughting and design
EIA:	Environmental Impact Assessment
ESRI:	Environmental Systems Research Institute
FAR:	Floor area ratio
FBZ:	Form based zoning
GDP:	Gross domestic product
GIS:	Geographic Information System
GISc:	Geographic Information Science
IDP:	Integrated Development Plan
NCGIA:	National center for geographic information and analysis
PDF:	Portable document format
RDBMS:	Relational database management system
SDF:	Spacial Development Framework
SPLUMA:	Spatial Planning and Land Use Management Act
SQL:	Structured query language
STATSSA:	Statistics South Africa
UK:	United Kingdom
UN:	United Nations
USA:	United States of America

Chapter 1. Background and context

1.1 Background and context

Globally, recent reports by the UN Population Department (United Nations 2015) and the World Economic Forum (2015), amongst others, have indicated that the world population continues to expand and that sub-Saharan Africa's population growth is expected to the highest in the coming decades. Together with the above, international reports also indicate that urbanisation in sub-Saharan Africa will amount to more than half of the urban population growth over the next 6 decades (United Nations 2014). Internationally, the move towards sustainable development (natural, economic and social) stem, in part, from the emergence of phenomena such as global warming, the effects of which have already begun to increase competition for resources and land. The present global economic downturn has the same effect: increased competition for resources and land.

Furthermore, technological advances have, in part, led to an increase in global unrest, as populations communicate their discontent about the management of cities and countries. These factors, along with many others, imply that the administration and management of urban populations and environments, in many cases, have to date been unsuccessful and will be under more strain in the immediate and medium term, not only to provide better environments for their growing populations but to be more effective and efficient in how this is done.

Land use management forms an integral part of the effective, efficient and sustainable management of urban environments. Internationally, since the mid-twentieth century, zoning has been one of the key tools that urban managers employ in their attempt to create environments that promote general welfare (mainly through the separation of land uses), protect property values and increase the local tax base, as well as promoting national and local objectives through facilitating particular types of development (Nedovic 1999: 1). In response to changes in planning theory and critiques of zoning as a tool, several other forms of land use management systems have emerged and many variations allow for local conditions and emphasis. Generally, three types can be identified: Euclidean zoning, flexible zoning and form-based coding.

Euclidean zoning is arguably the most common form of zoning and is based particularly on the premise of separating land uses that are deemed incongruent. Flexible zoning is similarly occupied with the exception of special zones in which higher varieties of uses and densities are permitted. Form-based coding, a system of development control that stems from the New Urbanist planning approach (Gajjar 2007), has in recent years had several international successes. Developed from the premise of creating quality environments (in particular in the public realm) while placing less emphasis on the separation of land uses, the system also requires more data on a micro level in order to be efficient and effective (Gajjar 2007). All of the above are subject to criticism.

Typically, there are common components to these schemes which include land use maps, zone maps, regulatory text pertaining to the various zones, processes and procedures, and people (including officials).

The zone maps are a spatial representation of the development objectives and city principles but typically must be read in conjunction with the regulatory texts. For the most part, in urban settings, the zoning is related to legally delineated land parcels or properties.

Geographic information systems (GIS) were developed during the 1960s, after the invention of computer technology as a tool used for the acquisition of digital spatial data, the cartographic presentation of data, spatial analysis, and the management of spatially referenced data. As an ideal tool for land use managers and others responsible for spatial applications, GIS technology and applications have evolved to keep track of the changes in the various fields where it is deployed.

There are presently (since its early development) two accepted models for representing geographic features:

a) The discrete object model displays land features as objects in a void and is represented in the digital realm as vectors defined by their dimensionality (0-D, 1-D, 2-D or 3-D or points, lines, polygons or volumes).

b) The continuous fields approach displays land features as part of a series of rows and columns, which span the entire extent of the dataset. In the digital realm, continuous fields are represented in the raster model (Longley 2005: 70-76).

Simply put, GIS are database systems with the added benefit of a geographic or spatial component. As with all systems, the functions include acquisition of data, storage and management of data, analysis of data and presentation of the data. The difference for all of these functions is the addition of the term 'geographic' or 'spatial'. The following figure shows the link between a spatial object and the database containing attributes about the object.

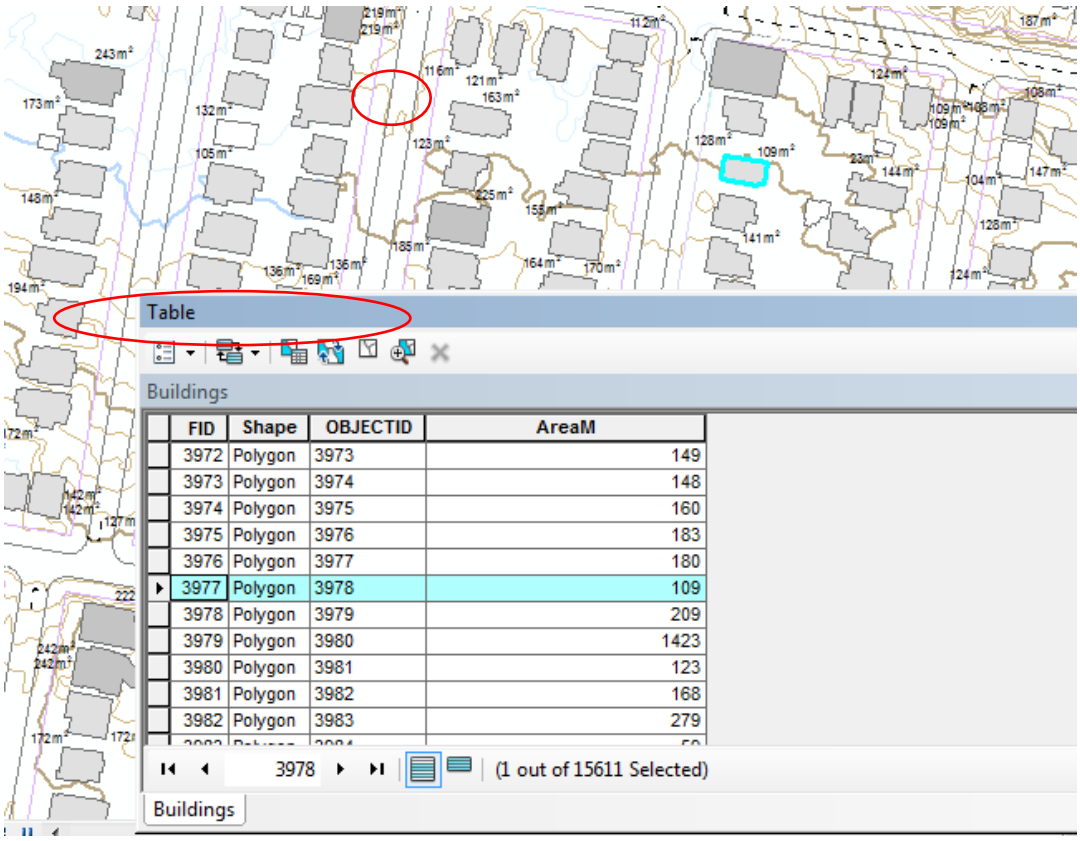


Figure 1.1: The link between spatial objects and database records (Source: Author)

There is one record for each spatial object in the database. Each record can have as many fields of information as are required by the characteristics of the spatial object.

As mentioned, in urban environments, zoning is typically attached as an attribute or characteristic of a legal land parcel, represented normally by a series of surveyed

points, connected by lines and combined to form an area or polygon. Another typical condition, as is corroborated by the investigation of the sample cities, is that the representation of the zone as an attribute is regularly done in isolation and not in conjunction with the zone regulations (typically height restrictions, coverage and floor area ratios (Briginshaw, D. M., Kahn, M., Ferguson, C. A. C. 2011: 34)) or the additional characteristics required to make fast, informed decisions, minimising the need for discretion. A further condition which should become evident during the examination of the sample cities, is that while GIS capabilities allow for the full range of spatial analysis (from exploratory visual analysis, queries, measurements, transformations, descriptive summaries, and optimisation through hypothesis testing (Longley 2005: 319-320)) typical, official municipal use ends with the exploratory visual analysis.

Major advances in the computing field and thus GIS capabilities over the past 25 years have meant that the use of both raster and vector models, simultaneously, have become commonplace in most arenas. The advances in database models and the rules that can be applied (particularly topology rules) have meant that the spatial relationships between databases, which in the past were separated by their model or dimensionality, can now be incorporated in a single database of near infinite size.

In South Africa, even two decades after apartheid, the legacy of focused development and application of the planning principles of developing urban fabrics that enhance public welfare and efficient location of land uses (economic opportunities related to residences), amongst others, still endure. The Spatial Land Use Management Act No 16 of 2013 (SPLUMA) (Republic of South Africa 2013) has been enacted in part to redress some of these. One of the objectives of SPLUMA is to include previously excluded areas in planning schemes. As it stands, nationally, South Africa mainly adheres to the Euclidean form of zoning, with some areas allowing for more flexible zoning. In particular, the inclusion of areas not previously under development control provides an opportunity for the application of form-based zoning. At the risk of profiling/stereotyping, these areas typically have highly pedestrianised populations reliant on public transport, with poor public realm conditions and a cynical approach

to local authority. All of the above factors point to form-based coding, or a variation of it, as being a potentially implementable system.

According to the White Paper on Spatial and Land Use Management (Republic of South Africa, Department of Land Affairs, 2001), South African cities are sprawling, which, apart from being environmentally unsustainable, perpetuates the legacy of apartheid planning by removing city residents from economic opportunity. This condition offers opportunity and need for the development of urban infill projects, redevelopment of brownfields and so forth. All of the above are opportunities for the implementation of new planning approaches for the betterment of South African cities.

Countrywide there is a shortage of planners, geographic data, and skills in both fields (Yeh 1999: 885, 886). The brain-drain, an ageing and diminishing base of experienced planners, focus on quick-gain projects, a perceived propensity of officials to make corrupted decisions, uninformed political interference at all levels of the decision making process and more, are all factors negatively affecting the ability of planners, through the use of zoning and other tools, to effect a better environment for the residents of the country. These same adversities create the opportunity for the development of a base of data that could improve decision making by including multiple variables and minimising the need or ability to make highly discretionary decisions.

This study focuses on the eThekwini municipality, which manages the area of Durban and its surrounding suburbs on the East coast of South Africa. The municipal area is the fourth largest contributor to the South African GDP per capita, with an estimated population of 3 442 361 (STATSSA Census 2011). The area administered by the municipality is 2368km^2 of which approximately 1385km^2 is urban. There are approximately 496 000 land parcels (plus an additional 10 000 leases) within the urban area. The city composite-zoning database shows 333 093 records of zoned properties.

Planning and development control in the city is informed by an Integrated Development Plan (IDP), as required and influenced by national government

objectives, which is translated to a Spatial Development Framework based on zoning and local planning principles.

Various departments within the municipality are involved in planning and require or use zoning data. These include, but are not limited to, the Development Planning Branch, Survey Department, City Architects, the Economic Development Unit, Transport Authority, Human Settlements, Environmental Planning and Climate Protection and so forth. Infrastructure services (Water, Sewerage and Electricity) are managed by their respective departments, while communication is mainly managed by the parastatal Telkom and private providers. The variety and number of departments that are actively involved in the planning process suggest a need for a high level of inter-department data sharing and cooperation as well as a need for up-to-date databases to be at the disposal of any department at any time.

The zoning approach in the city is typically Euclidean but with allowances made for special or flexible zones to encourage and/or incentivise economic development.

The municipality has a 'Corporate GIS' section sanctioned with the development and management of geographic data for use of the municipality and the public. The municipality has an enterprise license with the Environmental Systems Research Institute (ESRI), implying that GIS users in the municipality have access to the latest proprietary software. Even though the ESRI suite has advanced to 'geodatabases' allowing for topology rules, feature class relationships and more, the majority of the city databases are still served in shapefile format.

GIS as a concept/term is well publicised within the municipality and local and provincial planning fraternity.

1.2 Problem statement

As implied above, several departments within the eThekwini municipality continue to use dated GIS and database structures. The cause for this is uncertain but may stem from an unwillingness to move forward or to learn new technology, the pervasiveness of the 'shapefile' as an interoperable exchange format, budget constraints, older software providing functionality not within approved newer versions, ignorance regarding latest capabilities, or a combination of such factors. Whatever the reason/s,

not improving the geographic model of the city while it is possible, is problematic since the demands of society, in the contexts briefly outlined above regarding efficient, effective and accurate decision making, are not being met. Furthermore, with the rapid rate of change in technology in mind, the organisational, mental and skills updates that are required grow continually and may render those services and organisations not keeping abreast, obsolete in the near future.

One of the key stumbling blocks to the implementation of GIS in any institution of any scale is the cost of the system. The costs typically involves, amongst other things, advanced processing systems, peripheral hardware, software, data acquisition and management, and skilled staff (Yeh 1999: 887). The benefits of subscribing to the use of GIS in development control should be obvious and meaningful (albeit difficult to measure).

Anecdotal evidence suggest that the development (and investment) process in Durban is severely hampered by a lack of holistic property data and an inability of municipal front-desk staff to accommodate queries that deviate from anything other than producing a zoning category map or aerial photograph of the site. Furthermore, the eThekwini planning development branch's applications register (which cover the dense North-and-South central Durban) records a total of 5834 applications between 2012 and 2016 (eThekwini Municipality 2016). Of these applications, 5042 (86%) are relaxation applications such as encroachments on boundaries, frontage changes etc., implying changes to the urban fabric and morphology of the city-scape, affecting the public realm. Twelve percent of applications during this period deal with changes in use through special consent or rezoning, although it should be noted that anecdotal evidence suggests widespread increases in informal land use change. By not including regulations as they relate to each property, the process of establishing development rights of any given property becomes a cumbersome task for developers and officials alike. Apart from single sites, the potential development take-up of any given neighbourhood or block or street remain unquantified (unless performed by researchers or consultants on an *ad hoc* basis) which has potentially dire consequences for service infrastructure, quality of environment and so forth. As the competition between cities and regions increases, and investors and human capital are attracted to better opportunities, better quality of life (and environment), better services etc., the

need for more effective and efficient management of urban space will become paramount.

Another concern is that poor, incorrect and discretionary decisions based on poor quality, dated or incomplete data are being made. A topical example of this could be the case of 317 Curry Road in which a poor (or possibly biased) decision to rezone and develop a high rise property has led to a recent court order to halt and possibly reverse the nearly-completed high rise development at huge cost to the developer and city rate payers (Berea Mail, 13 May 2015). The cause of the error seems to be a failure to follow procedure. If indeed the error was not a biased decision, then it may have been circumvented by an official having a holistic database highlighting the current conditions of the site and surroundings (including owners), and the effect of changing the site zoning to one with more development rights.

Amongst the results of apartheid era planning is urban sprawl, the removal of the population from economic opportunity and focused development (amongst others, in terms of quality *and controlled* environments). National, provincial and local policies and plans all aim to redress these situations but without proper data, information and knowledge emphasis is often misplaced, resulting in wasted opportunities and money while failing to facilitate change. The opportunities offered by form-based coding as an alternative approach to zoning in the development of urban infill projects, brownfields development (as mandated by the SPLUMA) and potentially informal settlements, is far reaching but may only be achieved if the base information is available, spatially complete and accurate.

Systems that allow for highly discretionary decisions as a result of a lack of simple, clear and complete information potentially allow for the exploitation of these weaknesses by unscrupulous developers or other short-term-gain interests at the expense not only of city residents, but also of city/urban form and functions as a whole. Planners often have to react defensively against the initiatives of organised, well-resourced developers and lobbyists (Forester 1982: 437).

Currently there is no temporal aspect attached to the city zoning data. As such, there is limited ability track change and trends in zoning and land use change. Apart from

the database failing in temporal application, South African GIS practitioners have to date not accepted the international trend toward preparing metadata for GIS data, which includes dates that could highlight potential error in the data as a result of the age of the dataset.

Finally, the popularity of GIS and computing systems as producers of 'irrefutable evidence' to support interests of those who would abuse the weaknesses of the available data, the quality of the data and the variable scales of various databases are problematic. While GIS methods have evolved to allow values to be assessed and modelled along with physical facts, having data that is not complete and accurate, unduly weights interest over fact.

1.3 Research aims and objectives

1.3.1 Aim: To determine whether GIS in its current form is appropriate for the representation of development regulations in their conventional and alternative forms, using the case study area of the eThekwini municipality.

1.3.2 Objective 1: To describe the inter-related nature of 'Planning Theory and Practice' and 'Geographic Information Systems' with the aim of locating/creating a point of reference for zoning, form-based codes and GIS.

1.3.3 Objective 2: To identify the requirements of conventional zoning as it applies to GIS databases with particular focus on database models.

1.3.4 Objective 3: To identify the requirements of alternative zoning/form-based coding as it applies to GI databases with a particular focus on database models.

1.3.5 Objective 4: To propose and test, using case-study areas of varying character, a geographic data model which encompasses all possible requirements.

1.4 Research questions

1.4.1 Main question: What are the requirements of conventional and alternative zoning regulations and can GIS accommodate these requirements?

1.4.2 Research question 1: What are the planning and GIS theories that pertain to zoning and form-based codes and how do they relate to each other?

1.4.3 Research question 2: What are the requirements that a conventional zoning scheme makes of GIS in case of a full transition to GIS technology?

1.4.4 Research question 3: What are the requirements that a form based coding scheme makes of GIS in case of a full transition to GIS technology?

1.4.5 Research question 4: What database structure or model would allow for encompassing the requirements of both conventional schemes and form-based codes? Can this model be used in geographic areas of varying character?

1.5 Hypothesis

GIS, in its contemporary form, is able to represent the requirements of a full transition of conventional and form-based zoning to a GIS environment.

1.6 Structure of the thesis

Chapter 1 deals with the context, background and research questions. This chapter sets the scene for the remainder of the study and provides clear objectives that the rest of the paper will address.

Chapter 2 is a literature review, which reviews selected planning theory, zoning and geographic information systems. The review identifies the main geographic models and how they might be employed in the representation of zoning regulations. Furthermore, the review identifies planning theories and concepts that motivate the need for the study.

Chapter 3 looks at precedents around the world that use zoning and GIS. In this chapter, the use of GIS to represent zoning in six cities, spread across the globe, are explored to identify how these governments represent zoning and gain insight into how this, or improvements of this, can be deployed in the eThekwini municipality.

Chapter 4 provides more detail on the methodology employed. It describes the use of both qualitative and quantitative methods used during this study. In addition, it provides details regarding the purposive sampling in both the primary and secondary data sources.

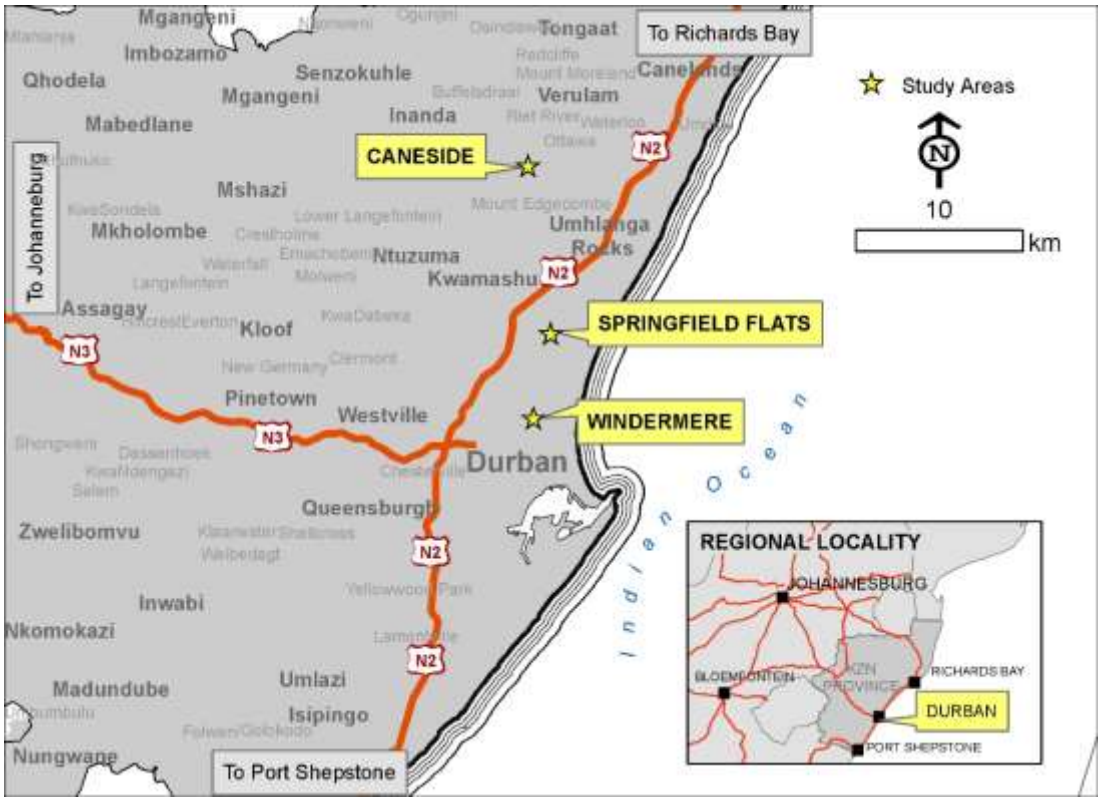


Figure 1.2: Purposive sampling used to ensure that areas of varying character was studied (author).

Chapter 5 provides the results, analysis and discussion regarding the data collected. The results from the qualitative data provide context and confirmation of anecdotal knowledge regarding the municipality's capabilities and systems while the qualitative data informs regarding the requirements of zoning systems and how a GIS model might accommodate these requirements.

Chapter 6 concludes with a summary, recommendations and potential future studies.

Chapter 2. Conceptual and theoretical framework

2.1 Structure and definitions

The objectives of this review are to investigate the various components that may exert influence on the use of geographic information systems (GIS) to represent the regulations that are implicit in various zoning categories across a city-wide jurisdiction.

While both zoning and GIS are planning tools, some of the theoretical frameworks in planning and geography are thought to have influence. The conceptual and theoretical framework will therefore focus on selected planning theories, zoning and geographic information systems (GIS).

2.1.1 Brief definitions

Some of the key concepts used in the paper are briefly defined below to aid the reader.

2.1.1.1 Zoning

Zoning is the legal process used by municipal authorities to control land use and development (Monmonier 1991: 72). This is typically done in formal cities and towns around the world by assigning land parcels or properties to a zone. Each zone has permissible uses – uses that are permissible with consent from the authorities – and prohibited uses. Furthermore, and paramount to this study, each zone has development controls attached to it.

2.1.1.2 Development controls

Development controls are those regulations that pertain to each zone which govern how and how much development may take place. These regulations typically include minimum lot size, setback lines, side and rear space, coverage and floor area ratios (Briginshaw, D. M., Kahn, M., Ferguson, C. A. C. 2011: 34).

2.2 Geographic Information Systems theory

Geographic information systems (GIS) grew and developed from the late 1950s and early 1960s after the advent of the computer. Early development happened slowly and

haphazardly, but some key developments shaped the course of the field. Some of the key developments occurred firstly because of the need for accurate measurements (in particular area measurements) which were difficult to obtain from paper maps. Secondly, because of the need to integrate and manage various types (different dimensions) and large quantities of data; and thirdly, because of the need to integrate multiple layers of information such as McHarg's overlay techniques (Goodchild and Hanning 2003: 364, 365).

According to well-documented definitions of a GIS, its purpose includes the acquisition of spatially referenced data, the storage and management of such data, spatial analysis, and the presentation, either on maps or alternative forms, of spatial data and analysis results (Avery and Berlin 1992: 202; Connolly and College 1998: 1). The standard definition given, GIS is also defined in the various fields in which it is deployed, placing specific emphasis on the field of use. These may include Toolbox, business, science information systems and societal definitions (LeGates 2005: 38). The fact that both town planning and zoning is specifically related to space makes GIS an ideal tool for deployment in planning, as was noticed early in the development of GIS (Dawwas 2014: 39).

While GIS is used in a great variety of applications and fields as a tool, recent developments (since the early 1990s) have been driving toward the development of GIS as a science in its own right. The ongoing debate within the GIS community regarding whether GIS is a tool or a science has led to the current trend toward viewing it as a science and has demanded the development of more rigorous procedures and standards (Goodchild and Hanning 2003: 382). It must be noted that commercial GIS only became available in the early 1980s with the release of the mini-computer.

Goodchild and Hanning (2003: 368) suggest that the development of the relational database management systems (RDBMS) structures was an 'early misstep' in the development of GISc. The nett result of the structure of the RDBMS was such that it required a split between geometries and attributes (which had significant effects on storage and spatial analysis). The ubiquitous shapefile is based on the RDBMS structure and the format still comprises the majority of databases within the municipal

GIS in South Africa. The late 1990s saw the advent of object-oriented databases which are able to store complex geometric information and the attributes of geometries within a single database. Apart from storing geometry, these databases also store topological relationships, feature relationships, Binary large objects (BLOBs) and more.

2.2.1 Theoretical frameworks

2.2.1.1 Cognitive geography

Cognitive geography is the study of how humans perceive the real world. Typically, humans differentiate between three spatial elements in the real world. These are:

a) landmarks: discrete locations that the receiver remembers and associates with;
b) the routes between landmarks or a sequence of landmarks; and
c) survey knowledge, which is a more advanced element where landmarks and routes are geometrically scaled (Montello and Freundschuh 2005: 8).

Goodchild suggests that humans see the world as a series of objects, while natural science reflects the world as processes of continuous variation across the study area (Goodchild 1992: 37). Traditional pen-and-paper maps used techniques to represent both objects and continually varying or fuzzy phenomena. Couclelis recognises that the age-old methods of cartography developed through trial and error in an effort to reduce the divide between human cognition and map symbology (Couclelis 1992: 71).

Spatial cognition is a universal trait with limited differences between cultural groups. There are four reasons for the universality of spatial cognition. These include, firstly, similar organisation of the central nervous systems of all humans; secondly, similar body structures and processes; thirdly, similar learning and socialisation techniques; and lastly, similar residential environments (Montello 1995: 490). All people from all cultures can, without undue effort, learn spatial concepts and procedures (Montello 1995: 496). What is important to consider in the South African setting, is that there are differences in spatial-cognitive ability between traditional and technologically-developed cultures (Montello 1995: 495). What is significant here is that the mapping of zoning controls and regulations may be a more understandable way of conveying information to the public as opposed to bodies of technical text.

2.2.1.2 GIS definition

Information systems may be defined as a combination of human and technical resources together with a set of procedures that aim to produce information in aid of some management role (Dale and McLaughlin 1988: 8). These information systems may be specifically created to deal with environmental, infrastructure, cadastral, social-economic or other themes (Dale and McLaughlin 1988: 9).

A GIS differs from these in that it contains a strong spatial component. Burrough and McDonnell (2005: 11) split the potential definitions into tool-based, database-based or organisation-based definitions. The tool-based definition is that GIS is a set of tools for collecting, storing, retrieving, transforming and displaying spatial data for a particular purpose or set of purposes. This definition is common, with some variation, throughout GIS literature. Davis adds managing, analysing, modelling and presenting geographic data for a large number of applications (Davis 2001: 13), but also goes further to include the functions of GIS as storage, retrieval and conversion (Davis 2001: 15).

Land information systems, a popular specialisation of GIS, that deal specifically with cadastral systems are defined as systems dealing with the acquisition and assembly of data, processing, storage and maintenance of land parcel data, and the retrieval, analysis and dissemination of the information (Dale and McLaughlin 1988: 8). Zoning is, in formal settlements, inextricably linked to land parcels.

2.2.1.3 Contributing sciences and major areas of application

There are several technologies and disciplines that have influenced, and currently still do influence, the development of GIS technology and science. Both the areas responsible for changing technology and the areas where GIS is applied, shape the development of the field by allowing what is achievable on the one hand and what is required on the other hand. Peuquet and Marble (1993: 11-13) highlight some of the fields that have been significant to the development of GIS as computer graphics and image processing, computational geometry, database management systems, software engineering and remote sensing.

The National center for geographic information and analysis (NCGIA) has a broader view and includes geography, cartography, remote sensing, surveying, photogrammetry, statistics, computer science and mathematics amongst others (Goodchild and Kemp 1990). The NCGIA lists the fields of major application as:
a) street network-based (address-matching, network analysis);
b) natural resource based (natural resource management, environmental impact assessments (EIAs);
c) land parcel-based (zoning, land use, ownership maintenance); and
d) facilities management (incl. service inventories, facility maintenance planning).

Goodchild et al in Longley (2005: 40-60), split the applications of GIS into four domains: Government and public service (including economic development and land use planning); Logistics and Transportation (particular emphasis on network analysis); Environment (apart from inventories, focus is moving toward dynamic simulation models to determine the impact of development scenarios on the environment); and Business and Service Planning (also known as retail planning, which uses in particular the field of geo-demographics).

For this study, the areas of 'Government and public service' and 'Land parcel-based' applications will be the most relevant since GIS is increasingly available to planners, including in South Africa, for extracting data from various sources, inputting data in models, linking spatial and textual data, displaying spatial data and querying results (Yeh 1999: 877-878). Also, as Yeh cites Newton (1986, in Yeh 1999), the more administrative tasks of planners include the management of land records, application processing and monitoring, and land use management, amongst others (Yeh 1999: 879).

2.2.1.4 Representing reality

Burrough and McDonnell (2005: 11-12, 28) suggest that spatial data and its attributes are comprised of position (or location) attributes and the spatial relationships amongst entities. De Man notes that all data and information have the three dimensions of space, theme and time (Peuquet and Marble 1993: 326) while Jack Dangermond, founder of ESRI, emphasises character and location of spatial entities but includes 'time' as being particularly relevant for GIS (Peuquet and Marble 1993: 34).

According to Vrana, the basic components of mapped data are theme, location and time. He goes further to suggest that typically, one of the characteristics is mapped, a second is used as a control, and the third (most often, the time dimension) is constant (Peuquet and Marble 1993: 287-288).

These components of reality are important since they will have an impact on what is represented on the map, define what characteristics the mapped features will have, and will implore cognisance of the time dimension (data as a snap-shot view of current zoning conditions or characteristics).

2.2.1.5 Components of a GIS

Understanding the components that make a geographic information system is useful since the components of zoning schemes are similar and the overlaps between the two may influence each other to large degree. According to most sources, such as the NCGIA core curriculum (Goodchild and Kemp 1990; Fazal 2008: 13-14), the typical components of a GIS include:

a) Data: spatially referenced data and non-spatial data which are used as input into inventories, analysis, etc.

b) Hardware: this includes processors and storage devices, and peripheral devices used for input and output.

c) Software: used for the management and analysis of spatial data.

d) Procedures: which are engraved within the software and are typically based on algorithms and peer-reviewed methods. Others relate to methodologies that include various methods, in particular sequences, to arrive at a solution to particular problems.

e) People: this component includes users of varying skills and with varying interests. While the author does not possess statistics regarding the most active sector of users, it is known that amongst the larger proportions, are users in the local government agencies. Increasingly, the users and beneficiaries of GIS functionality are the public.

f) Networks: which, since the advent of the Internet and mobile technologies, influence the dissemination and increasingly, the collection of geographically referenced information.

2.2.1.6 General functions of a GIS

In line with the generally accepted definition of a GIS, the typical functions of a GIS are usually said to be the acquisition and verification, compilation, storage, editing, management, manipulation, retrieval and presentation, analysis and combination (Fazal 2008: 15-16) of spatially referenced data.

The 5A definition in France – acquire, display, archive, abstract and analyse (Le Ber and Bucher 2013: 5) – is simpler but the functions remain the same. Many of these functions relate directly to typical zoning schemes.

2.2.2 Geographic models

Geographic data representation is one of the key debates within the GIS science. Two theoretical frameworks exist, based on widely different approaches. Couclelis describes the divide as akin to that of Atomic versus Plenum ontologies in modern physics (Couclelis 1992: 69). The author understands that this difference is significant. The Object versus Continuous field approaches in geography and GIS are important to understand since they represent the world within a digital frame which humans/ geographers use to simulate reality and planners use to make decisions regarding the urban form.

2.2.2.1 Continuous fields approach

The raster model (as the continuous field approach is termed when used within a computerised environment), is based on the premise that the entire world is represented as "a finite number of variables, each one defined at every possible position" (Longley 2005: 72). In simple terms, for any particular theme (one theme at a time), the entire surface of the study area/world is divided into an array of rows and columns. Every cell indicates whether it is part of this theme or not by, typically, binary values (See Figure 2.1 below). The nature of this approach lends itself to natural applications and themes where exact boundaries would be modelled inappropriately by vectors, for example, soil classes or vegetation, which do not terminate along exactly surveyed boundaries. An everyday example of a raster is aerial photography, where the cell value is a combination of integers related to colour bands.

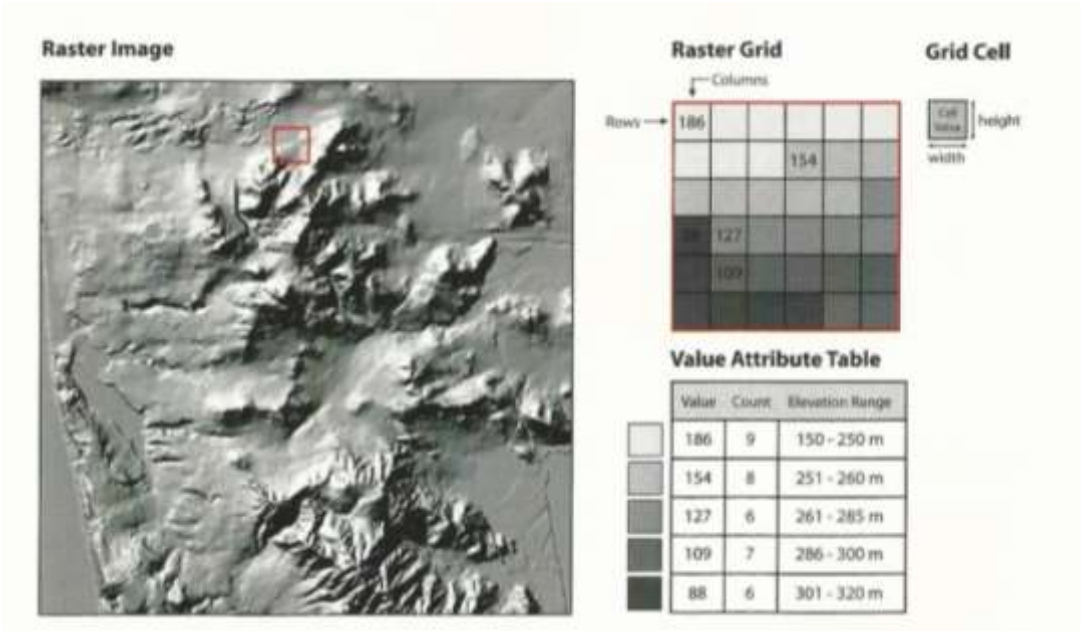


Figure 2.1: Raster GIS data representation (Pamuk 2007: 27)

Simple data structures and non-complex overlay procedures notwithstanding, raster data do not represent man-made shapes and perimeters well (Fazal 2008: 113). Property boundaries, for example, are not fuzzy as is the boundary between two raster zones, but are exact watersheds connected to exactly surveyed beacons. The resolution of rasters may be increased to reduce apparent fuzzy effect but the increases in file size make it impractical.

The capabilities of raster systems include operations that can be performed on local cells, neighbourhoods of cells, extended neighbourhoods or zones. Respectively, these include functions such as recoding of cell values, passing filters over local neighbourhoods for smoothing or edge-enhancement effects, calculating distances from cells or determining the areas, perimeter or shape of zones of cells (Goodchild . 1990: 5-4-7).

2.2.3 Discrete objects model

The discrete objects view of the world places objects (land features) in space (a void). Typically objects are represented based on their dimensionality at the acquisition scale (Longley 2005: 71). The scale at which the information was captured into the digital system is an important consideration since the dimensionality of objects or features changes, depending on the acquisition scale. For example, at a scale of 1:2 000 000, a

city is represented as a 0-D point. The same city at a scale of 1: 50 000 is represented as a 2-D polygon. The choice of acquisition scale relies heavily on human or application purpose. Points (0-D), lines (1-D), polygons (2-D) and volumes (3-D) are resulted objects based on decisions made by the geographer or planner that suits his/her purpose. This representation as objects allows for the definition of spatial relationships between objects in space. Typical spatial or topological relationships may include objects that fall within other objects, objects that are near other objects, objects that cross others, etc. Similarly, there are relationships between objects of varying dimensionality (for example, point-to-point relationships, point-to-line relationship and point-to-polygon relationships among others). Early spatial statistics, which aided the development of the fields of GIS and spatial analysis, were particularly concerned with spatial autocorrelation (the relationships between points, which incidentally aided in the development of Waldo Tobler's first law of geography (Tobler 2004)). Tobler's first law states that "everything is related to everything else, but near things are more related than distant things" (Fazal 2008: 248). It is noted that this natural geographic phenomenon, rightly or wrongly, resonates with the agglomeration of like uses near each other.

The term typically used for computerised representations of the discrete objects theory is the vector model. Vector models are particularly good at representing exactly measureable land features (such as surveyed, legally defined, land parcels) and produce high accuracy outputs. According to Fazal, vector data structures also have compact data structures which make them easily projected and transformed (Fazal 2008: 113). See Figure 2.2 below.

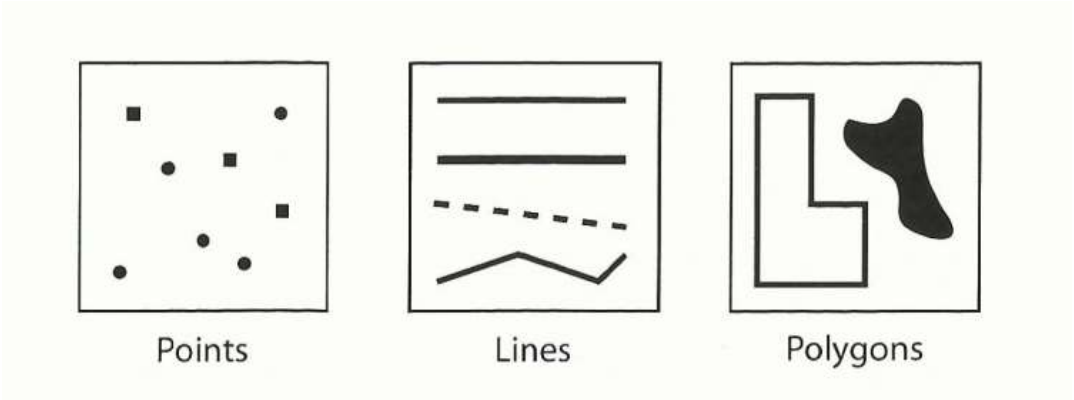


Figure 2.2: Basic vector GIS geometries (Pamuk 2007: 27)

There are several disadvantages with using the vector model. These include issues such as the size of databases (storing coordinates for each vertex along the geometry of lines or polygons); conceptual limitations such as the measurement of absolute location as opposed to relative location of all things on earth (Goodchild 2003: 367), and weak representation of temporal or dynamic data. The complex data structure also leads to complexity in overlay operations (Fazal 2008: 113).

The capabilities of the vector systems are different from raster in that some operations are slower, others faster and some more accurate. Area measurements on polygons are more accurate than counting cells in a raster, but overlays are slower (Longley 2005: 331). Some of the capabilities in the vector system include simple displays and queries. Questions can be asked of the database using Standard Query Language (Goodchild and Kemp 1990: 14-14). Furthermore, features can be dissolved, merged or reclassified based on their attributes (Longley 2005: 80) and topological overlays. Topological overlays involve using planar enforcement to calculate new intersections wherever two lines cross, creating new objects (Longley 2005: 184).

In 1992, Helen Couclelis gave advice for the next generation of GIS users. Appropriate to this study was her statement as follows:

> "Choose your system to fit your main purpose, All applications with the word "management" in their title require an object perspective, more consistently implemented in vector-based GIS"(Couclelis 1992: 75).

Zoning, being a land use management tool, is most accurately represented by the vector approach and naturally gravitates to the use of polygons with attributes and to having spatial relationships with conditions implied by the regulations attached to zones. The conditions may be represented as either points, lines or polygons.

2.2.4 Note on the object-fields approach

The object-fields method of combining continuous fields and discrete objects has potentially significant implications and applications for town planning. The use of continuous fields to relate information regarding an object means that there is potential to model much larger effects or situational position on any given point (for all points). This implies that a much more holistic approach (which may include less tangible

characteristics of a location) may be possible. For this application, it is less relevant but cognisance should be taken of the continued search for alternative ways to model the world (see Cova and Goodchild 2002).

2.2.5 Non-spatial data types

Since many of the regulations within zoning may only be represented in the GIS database as attributes rather than spatial objects, it is important to understand non-spatial data types.

2.2.5.1 Scales of measurement

The simplest definition of the types of attributes that one can expect to deal with in a GIS include qualitative and quantitative attributes. Qualitative attributes are typically those descriptive values that do not have mathematical or statistical meaning. Quantitative attributes, on the other hand, provide measures of magnitude with mathematical meaning (Davis 2001: 53). Within a land information system, Dale and McLaughlin (1988: 158) suggest that there are three types of data. These are alpha-numeric data, which are descriptive in nature, graphical data which are seen as maps, photomaps or aerial photographs, and numerical spatial data, which depict some value about a record.

The measurement level that is used in the database is determined by a couple of variables. The nature of the phenomena will partly decide what is measurable, the purpose of the database will have influence over what is measured, and the scale at which measurement happens will determine what we are able to measure (DeMers 2000: 29).

Typically, according to most sources, the accepted data types or scales of measurement include:

a) Nominal scale: descriptive values that depict names or characteristics that do not allow direct comparisons with other objects through mathematical or arithmetical operations. These values typically name objects or classes (DeMers 2000: 29), for example, “Residential Zone” or “Berea Red Soil” or ObjectID = “125487”.

b) Ordinal scale: ordinal values are categorical data that have a natural or assigned order. The difference between classes is unknown so mathematics or arithmetic does

not make sense (Longley 2005: 69). For example, soil suitability may be good, average or poor.

c) Interval scale: interval values are numeric values where the difference between values on the scale makes sense. However, interval values do not have an inherent zero, meaning that absolute or relative magnitudes are senseless (DeMers 2000: 31; Longley 2005: 69). For example, temperature scales are interval values since the difference between 10 and 20 degrees are the same as the difference between 80 and 90 degrees. However, 0 degrees doesn't imply "no temperature" and 100 degrees is not twice as hot as 50 degrees.

d) Ratio scales: data on a ratio scale are numeric values with an inherent zero. The ratios between different values on this scale make sense. For example, a distance of 0m really means "no distance" and 6m is twice as far as 3m. (DeMers 2000: 31) suggests that this the most useful of the numeric scales.

e) Others scales and multiple representations: Burrough and McDonnell (2005: 28) split the scales of measurement by the operations that are allowed on each scale. In this case, nominal values can only be assessed by logical operations, ordinal values can be expressed in logical and ranking operations; integer values can be used in logical and integer arithmetic operations; and real (ratio) numbers can be used in all logical and numerical operations. He adds two additional data types. Boolean values allow only logical operations (0 or 1, True or False) and Topological values which are whole numbers that indicate the links/ relationships between entities.

Longley, Maguire and Rhind (2005: 69) and O'Sullivan and Unwin (2002: 14) mention other data scales that are not prominent but which could be used for particular types of measurement (and hold their own dangers). In particular, cyclical data may be found frequently in GIS because of angular measurements where differences, means and other values are affected by the cyclic nature of the scale (0-360).

What this means is that questions that can be asked of a database (the analysis that can be performed on the data) are dependent on the scales of measurement used to store the data in the database (Burrough and McDonnell 2005: 28).

These scales of measurement have to translate into database field types. The Microsoft office support document indicates the following field types that are available for most

office databases: Attachment, AutoNumber, Calculated, Currency, Date/Time, Hyperlink, Memo, Number, OLE Object, Text and Yes/No (Microsoft 2016).

ESRI ArcGIS software has slight variations to the Microsoft list: Short Integers, Long Integers, Single-precision Floating point, Double-precision Floating Point, Text, Date, BLOB (Binary Large Objects), Object Identifiers, Global Identifier, Raster, Geometry (ESRI 2016).

Nominal and ordinal data can be accommodated in text type fields. Integer and ratio data can be placed in Short Integer, Long Integer or Floating Point fields. BLOB fields, Raster fields or OLE object fields are able to store image data within the database. This may have significant impacts for representing diagrammatic regulations such as those found in form-based coding.

2.2.6 Critiques of GIS technology

Since the world is infinitely detailed, representations within a GIS (or any map) are a generalised sample. The decisions about what gets sampled, at which scale, how generalised or to what level of detail, are made by humans, typically with a particular purpose in mind (Monmonier 1991: 76; Scott 2003: 250). These abstractions have the potential for reality to be skewed by either ignorant or malicious practitioners.

Absolute measurements are widely accepted as the preferred locational concept in GIS. Many applications within the social sciences are more concerned with relative position, situation or order of magnitude, rather than with absolute measurements. The field of planning in particular appreciates relative position or situation as opposed to highly precise absolute measurements. Legal frameworks such as zoning or surveyed properties on the other hand, benefit from rigid absolute measurements.

One of the key critiques of GIS is the data centeredness of the approach. Although GIS as a tool for planners has evolved with planning to include methodologies such as multi-criteria-decision-making (wherein attempts are made to evaluate values and principles alongside empirical/physical facts), the potential for the data-centred nature of GIS to override other parameters remains a possibility (Dale and McLaren 1999: 129).

Although software packages have in recent years been made more user-friendly, GIS operators still require significant skill. This excludes, and potentially intimidates, many of those who should be using it. Apart from this, there is real potential for misuse and misinterpretation by many of the users of GIS who may lack knowledge in the theory of spatial analysis and GISc (Goodchild 2003: 376).

Apart from uncertainty that arises from the methods used in the preparation of GIS data (abstraction decision, representation decisions, errors in capture process), more fundamental error propagation could develop because of the potential epistemic uncertainty in some data and the inherent stochastic uncertainty within other, particularly natural, data (Mosadeghi 2013: 2-3).

Monmonier's "How to lie with maps" details examples of how maps and spatial data could be used to misinform users or readers (Monmonier 1991: 78-81). The fact that maps and spatial data are prepared with a predefined purpose means that they are always subject to abuse through ignorance or malicious intent.

Maps, more so than GIS, have also been critiqued for their role in power relations. Harley wrote that maps are never autonomous or free from the politics of knowledge (Crampton 2001: 240), implying that they have a significant potential for abuse of power.

2.2.7 GIS in the South African context

GIS a relatively new technology on the global scene and more so in South Africa. While the concept has been known to academia and researchers from the onset, the deployment of GIS as a 'mainstream' technology was retarded in South Africa, not only by the country's geographic location in the developing world, but also by international sanctions and other barriers imposed because of the country's apartheid policies (1960s-1990s). During the 1990s, the mini-computer, the greater availability of spatial data and the interest shown by key government departments led to an "explosive growth" (Cilliers, De Klerk and Sandham 2013: 71) in the GIS sector. Growth in the GIS sector has increased since the 1990s, reaching a milestone in 2012 with the introduction of GIS as part of the high school geography curriculum. In terms

of planning, Cilliers et al. (2013) show a relatively consistent output of articles and dissertations using GIS in the field of Town and Regional Planning.

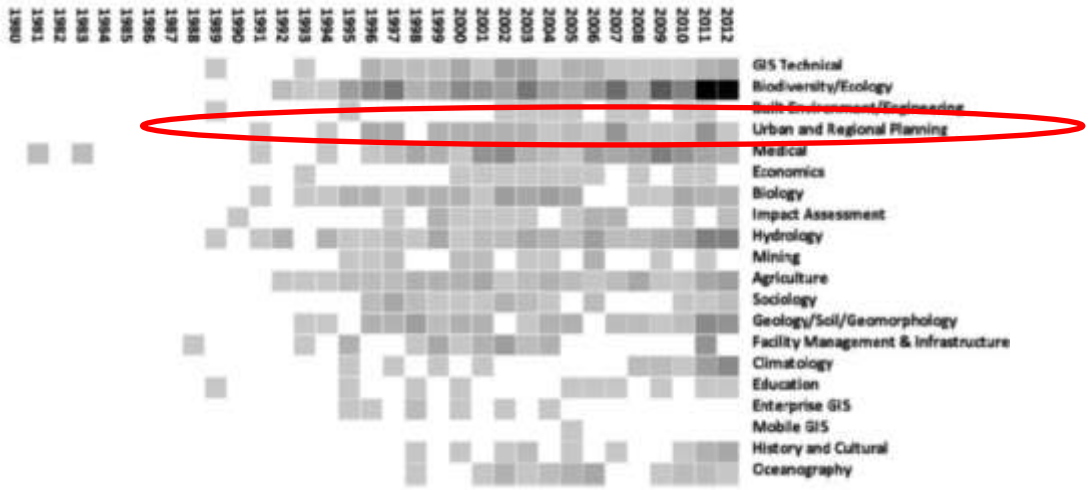


Figure 2.3: Extract from Cilliers, De Klerk and Sandham (2013: 85)

The same research also points out that Kwazulu-Natal has produced an above average number of articles and dissertations in fields related to GIS (Figure 2.3 above shows relatively high numbers of articles produced between 2005 and 2012; and similar figures for dissertations between 1995 and 2004, although slowing down since 2005).

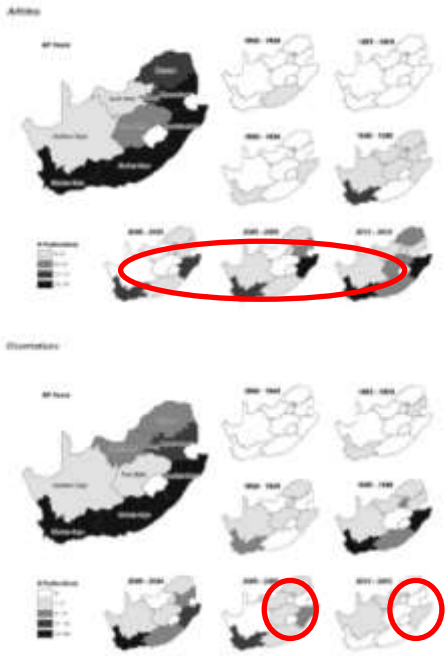


Figure 2.4: Extract from Cilliers, De Klerk and Sandham (2013: 84)

2.3 Substantive planning theory

2.3.1 Rational planning or systems planning framework

This approach developed in the period immediately after the Second World War and in the early days of computing. There is no comprehensive rational 'planning' theory (Boyne, Gould-Williams, Law and Walker 2004: 330); instead it stems from rational theories developed by thinkers of the time, such as Karl Hopper (Innes and Booher 2014: 197). Under the influence of the technical-oriented fields of engineering, land survey, architecture and so forth, what used to be the art of planning changed to the science of planning (Hall 1988: 327). The key idea during this time was that only the analysis of large amounts of empirical data could provide the correct solutions for rapidly expanding urban populations. Dawwas (2014: 39), referring to Forester's 'Planning in the face of power', highlights three assumptions of planners at the time regarding information:

1. Information is a 'value' and politically neutral.
2. Distinctions between 'objective' facts in a computer and 'subjective' opinions and values of individual interests could be made.
3. The more information planners had, the better the quality of planning would be.

These assumptions have been heavily criticised by subsequent planning theories. Communicative planning theorists for example suggest that rational planning is good only when "values and goals are settled" (Innes and Booher 2014: 197). The context in which systems planning developed provides a slight reprieve from these critiques. Hilary Ballon, speaker at the 2011 "Zoning the City" conference in New York, highlights the "deficit of information" that existed in the time before the 1950-60s by stating that the virtually no land use information on the more than 800 000 New York properties existed at the outset of the 1961 Zoning Resolution (Zoning the City. 2011).

Boyne et al. (2004: 330-332) suggest there are two main areas which cause difficulty for rational planning. These are technical and political in nature. On the technical side, the resources (including information) and technical expertise required are often insurmountable. Political aspirations, on the other hand, do not align with the clear statements of objectives used in rational planning, and organisational power often shifts toward politicians who prefer fuzzy, non-technical objectives. In the South

African context both of these limitations severely hamper the use of systems approaches in planning.

Modernist planning, which includes comprehensive planning or blueprint planning, derives from the systems planning approach. Zoning is one of the key tools employed in the comprehensive planning approach (Scott 2003: 239-240) and as such zoning is inextricably related to rational planning.

2.3.2 Advocacy planning

The Advocacy Planning Framework (Davidoff 1965) resulted as a response to the perceived failures of rational planning: in particular, as a criticism to the exclusionary approach of rational planning on the premise that an "objective reality exists where all stakeholders would agree" (Dawwas 2014: 40). Of particular interest in this case, advocacy planning was the first significant planning approach that diverted emphasis from quantitative, rational methods to methodologies including more 'value' or qualitative inputs. While this changed the larger planning landscape (and continues to influence it), it did not have a great effect on zoning as a planning tool. Advocacy planning however does resonate with the central theme of zoning (as described below) in that its aims include justice and the "general welfare" of people (including all groups but particularly 'vulnerable groups', which could be any property owner or civilian facing unscrupulous developers).

It should be noted that this and subsequent planning theories, which all emphasise the importance of community values, also changed the way in which GIS is used in planning. Specifically, the amendment of strictly Boolean operations towards GIS-integrated multi-criteria-decision-making has continued evolving to ensure that GIS remains a highly valuable tool in planning (Dawwas 2014: 40). Advocacy planning's concern with social justice has endured and still influences planning today (LeGates and Stout 2015: 427).

2.3.3 Communicative planning

This is an approach roughly based on the German philosopher Habermas's theory of communicative action (Innes and Booher 2014: 199). In short, the theory suggests that the process of communication will lead to improved social understanding and

consensus (Bolton 2005: 2; Dawwas 2014: 40). In terms of planning, Innes argues that the process of real communication between stakeholders and the shared interpretation of information, changes the actions of stakeholders (including planners) and results in better decisions.

Of interest here is the role of information (including geographic information) and how it may change the outcomes of the planning process, and also the impact of information dissemination on people. It is argued that when information has become embedded in the thoughts, practices and institutions of a community, it influences actions, assumptions and problem definitions (Innes 1998: 56; Innes and Booher 2014: 202).

As with systems planning, there are few guidelines, rules or fixed theory in communicative planning theory, because proponents believe that each situation is unique (Innes and Booher 2014: 198). These approaches also draw significant critique from other planning theorists and such critique typically includes that the process is inefficient, that the focus on process rather than outcome is misguided, that discussion cannot produce knowledge or change fundamental values, and so forth (Innes and Booher 2014: 198).

The importance of communicating information to all stakeholders in planning processes is paramount from the communicative planning viewpoint, and this includes zoning information and regulations that affect all the citizens of a city. This is vital in South Africa where large portions of the urban population have only recently been exposed to the concept of land use controls and view them as "illegitimate or irrelevant" (Parnell and Pieterse 2010: 16).

2.3.3.1 Habermas's communicative action theory

The communicative planning framework is loosely based on Habermas's communicative planning theory. The theory seeks to arrive at a position where consensus between various stakeholders may be reached in a rational manner. Habermas insinuates that communicative action toward coordinating individual actions is universal (Flyvbjerg 1998: 5).

First, an independent concept of rationality is defined through a communicative rationality, which is comprised of communicative action and strategic action (Ross and Chiasson 2011: 125). The strategic actions of individuals are divided into 'open strategic action' and 'hidden strategic action'. Open strategic actions are acceptable and may be welcomed, whereas hidden strategic actions are detrimental to consensus seeking. This concept of rationality is presumed to free of individualistic bias and is located in Habermas's two-tier concept of society.

Society, for Habermas, is comprised of the 'lifeworld' and the 'systems paradigm'. In turn, the lifeworld for each individual is a set of skills. These skills include individual skills that are used to determine a course of action in a particular situation, and socially acquired skills that inform the individual about what actions to expect in any given situation. The lifeworld is the backdrop for communicative action. It is important to note that where the lifeworld of participants in communicative action or discourse is similar, agreements are made more easily. In a complex society with dissimilar lifeworlds, the need for discourse is greater (Ross and Chiasson 2011: 127).

The systems paradigm is comprised of economics and politics (respectively, money and power). The system constantly steers and disrupts communicative action. Much of the critique on communicative planning stems from Habermas's limited concern regarding this effect on the lifeworld by money and power. Flyvbjerg (1998: 47) cites Foucalt in stating that power is always present and goes on to assert that it would be "meaningless" to work with theories where the concept does not consider power.

For successful communicative action, Habermas's theory requires certain conditions. Comprehensibility is one of these conditions, which Habermas only views as a first step towards deeper understanding (Ross and Chiasson 2011: 125). For Habermas, comprehensibility applies to speech in particular, but it also applies to other types of communication such as maps. Comprehensibility is the foundation to all that follows in the effort to reach perfect communication and as such is key.

Following 'comprehensibility', there are the validity claims that each speech act comprises and/or implies. For acceptance of the guarantees implicit in the communication, 'truth', 'truthfulness' and 'legitimacy', which respectively translate

to ‘external’, ‘subjective’ and ‘social’ must be met. An example that illustrates the concept best translates to ‘the world’, ‘my world’ and ‘our world’. Communicating laws (via either text or maps) seem to resonate with the objective but must also appear to be fair and be legitimate. Failure to meet any of the validity claims implies that agreement will not be reached and that the argument will move to discourse. For acceptance of the obligations that arise from the communication, the speaker’s actions or communication must be consistent with the communicative act (Ross and Chiasson 2011: 126).

In the communicative action theory, if any of the validity claims are not met, the argument moves to discourse. Habermas theorises that for agreement to be reached during discourse, all participants must approach the debate with a willingness to be converted by the better argument as opposed to rhetoric.

A key weakness of Habermas’s theory is that there is no alignment between the utopian ideal and reality or intention and actual implementation (Flyvbjerg, Richardson, Allmendinger and Tewdwr-Jones 2002: 46).

The theory describes the utopian situation but does not provide the details on how to achieve the situation (Flyvbjerg et al. 2002: 47). Communicative planning may suffer the same fate in that it attempts to attain a wonderful situation without ever being able to reach the goal (Flyvbjerg et al. 2002: 57).

2.3.3.2 Power discourse

There are many facets of the power discourse that have a bearing on planning and zoning, as a tool in planning. In this section Habermas’s scant attention to the role of power in communication, Foucault’s assertion that power is ubiquitous and inextricably entwined with knowledge, public choice theory, Harley’s suggestions that the rhetoric of maps are tools of power, and Forrester’s views of ad hoc and systematics types of power abuse, are briefly reviewed.

Habermas’s theory aims to create a situation where consensus amongst participants of a discourse can be reached using validity claims, an equal participation approach and the absence of distorting powers (Flyvbjerg et al. 2002: 46). Habermas’s theory of

communicative action states that the utopian speech act occurs against the backdrop of the lifeworld. The lifeworld is comprised of individual and societal skills, which are constantly steered by money and power. Habermas's scant attention to the power dimension is possibly the greatest source of critique of the communicative action theory when applied to planning.

Habermas pays little attention to cultural divisions, or issues relating to identity, or how communicative rationality will develop in the face of the overwhelming non-communicative status quo (Flyvbjerg et al. 2002: 49). Discourse, according to Habermas, is required when agreement between participants of the speech act cannot be reached. Agreements are reached more easily when the lifeworlds of the participants are similar. In the South African situation, participants have greatly varied lifeworlds in terms of education, culture and expectations.

Habermas's validity rules contain another key aspect to the power discourse in 'legitimacy'. For rules or laws to be acceptable, they must be perceived to be legitimate. In the South African context, with dual systems, formal and traditional, formal laws are often not considered legitimate.

Philosophers such as Machiavelli, Nietzsche, Foucault and Derrida have all asserted that communication is permeated by power at all times (Flyvbjerg et al. 2002: 47). The students of power would surmise that there is no escape from power (Flyvbjerg et al. 2002: 61). Those who study power maintain that self-interest and rhetoric are typically the key ingredients of communication rather than consensus-seeking or un-coerced, non-strategic action (Flyvbjerg et al. 2002: 47). Foucalt suggests that power, or politic, is everywhere.

Public choice theory is premised on the assumption that persons employed in administrative institutions, like any individual, will be motivated by self-interest or alternatively, are rational self-interest maximisers. While legislators or administrators may not directly aim for monetary gain, they will act in a manner to get re-elected in order to keep the benefits of being in office (Fraietta 2012: 1939). This assumption has been proven correct using empirical evidence in American senate campaigns (Fraietta 2012: 1940). Bent Flyvbjerg's study in Aarlborg found that planners in the

city were self-interested and would manipulate public debates and technical analyses to further their own cause – this all while representing institutions supposed to be in the public interest (Flyvbjerg et al. 2002: 60).

Rationally ignorant voters form another pillar of public choice theory. The assertion is that the opportunity cost of collecting information about the politics and the low likelihood of the individual to make a difference, makes staying ignorant of political processes a rational choice for voters or citizens (Fraietta 2012: 1940). Similar behaviour may be expected from citizens in relation to zoning and development controls, although a 2005 study of 68 medium-sized cities in America, found that 57% and 36% of respondents respectively were very active or somewhat active in local zoning: that is 93% active in zoning (Fraietta 2012: 1945). Thus, it may also be that given access to digestible zoning data, the citizenry may become more involved.

Foucault suggests that power and knowledge are inextricably intertwined and that knowledge and rationality are not objective (Flyvbjerg et al. 2002: 51,52).
Flyvbjerg suggests that in the real world, social and political alike, self-interest and conflict will not succumb to idealistic or utopian ideals such as those of Habermas (Flyvbjerg et al. 2002: 62).

Both Habermas and Foucault agree that the misuse of power and rationalisation of that abuse is one of the most dire problems of modernity; however they disagree on the approach to correct the situation. Habermas believes it can be done by gaining consensus in a power-free, equal environment, while Foucault suggests it can only be done by strategically being in a state of conflict with power (Flyvbjerg et al. 2002: 54,55).

J. B. Harley's credentials as historical geographer and co-author of the 'History of cartography' project made him uniquely qualified to comment on maps as constructs of power (Crampton 2001: 236).

Typically, maps may be understood to perform three key functions. These are reference maps which provide locational information, analytical maps that provide

insight into patterns and relationships, and thematic maps, which show various characteristics of spatial features (Kent and Klosterman 2000: 189).

The ‘History of cartography’ project showed how the rhetorisation of cartography played a role in the normalisation of power relations and how maps were used as tools in subjugating populations and territorial power struggles (Crampton 2001: 239).

Maps are a more powerful rhetoric than communicative devices and as such can be examined as texts (Crampton 2001: 238). Maps are socially constructed texts and thus can be interpreted differently and contain fragmentations and contradictions (Crampton 2001: 241). Harley stated that maps have never been autonomous or above the politics of knowledge (Crampton 2001: 240).

Harley looked at two areas of power in cartography. These were the power of the map patron (kings, statesmen etc.) over the cartographer, and the power of the cartographer him-/herself. From this, he concluded that there are internal and external power influences in maps (Crampton 2001: 241).

One of the key implications of Harley’s work, to counter the internal and external biases, is the importance of multiple perspectives and views of spatial data (Crampton 2001: 244). Geographic visualisation through distributed digital mapping may be the method for Harley’s theory (Crampton 2001: 236). Virtual reality or digital geographic visualisation is about data exploration rather than static representation. It is process rather than a presentation (Crampton 2001: 244).
Recently, the convergence of spatial technologies such as GIS, remote sensing and digital cartography has resulted in interactive, query-able maps that can be disseminated on the Internet. These are connected to various information sources which the map user can access in a user-defined environment (Crampton 2001: 247-248).

There are significant differences between those who research mapping as a tool and those who critique mapping and the mapping process (Perkins 2003: 341), and it is unlikely that the two schools will reach agreement soon (Perkins 2003: 347).

Perkins cites a range of researchers who have conducted work into the efficiency of map styles, the communicative effectiveness of maps, user perceptions etc., and concludes that the majority view maps as atheoretical representations of the world (Perkins 2003: 344). He also asserts that current cartographic practices are much more nuanced and that maps today are thoroughly understood to be social products (Perkins 2003: 346).

Planners often have to react defensively against the initiatives of organised, well-resourced developers and lobbyists (Forester 1982: 437). In the lifeworld where planning and mapping occur, money and power are constantly influencing the direction of things.

Planners shape the information that civilians may have and also the trust and expectations of civilians. Information is a complex source of power in the planning process and control of the information is a key source of the power that planners wield. Misinformation comes in several forms but generically speaking may be either ad hoc or systematic (Forester 1982: 438). Misinformation is an abuse of power.

There are several identifiable styles of planner, from technocratic through advocative and structuralist to progressive. Each style of planner views and deals with power and politics differently. Progressive planners, who are defined as combining the insights of liberal and structuralist planners but go beyond that to recognise the political-economic power, may systematically distort the information given to the citizen body (Forester 1982: 440).

Progressive planners, unlike other styles of planner, do not believe that most instances of misinformation are accidental and that here is a need for planners to anticipate the way in which misinformation occurs so that corrective measures may be taken (Forester 1982: 441, 445). Political-economic structures often determine what is communicated, who it is communicated to and also when, where and how communication takes place (Forester 1982: 443). For unbiased and informed citizen action, Forester, similar to Habermas, recognises the need for comprehensibility, sincerity, legitimacy and accuracy, translated respectively to minimising technocratic

jargon, building public trust and avoiding manipulation, obtaining public consent and providing information that is accurate (Forester 1982: 444).

Since there is no guarantee against manipulation in planning (Forester 1982: 444), informing the public earlier in the planning process is one of the suggested methods to minimise misinformation (Forester 1982: 445). Informing the public implies that information is provided in a way that the public can understand it best. Reports must be made "intelligible" (Forester 1982: 451). This applies not only to reports but to regulations, mapping and official communications as well.

2.3.4 New Urbanism

The New Urbanism framework is the most recent development in planning theory and has adopted many aspects of the pre-existing theories (including environmental planning and others not discussed here). The origins of the New Urbanist movement are located in attempts to redress the conditions in urban areas which have been sprawling, fragmenting and exhibiting social disconnection since the end the Second World War. The movement attempts this redress through changing the built environment in a way that would produce compact, sustainable cities; that would enhance social cohesion by promoting a public realm that inspires behaviour; and that encourages pedestrian use and interaction (Trudeau 2013: 436-438). The movement is distinctly American and hankers toward pre-car/bus urban typologies as described by Fischel (2004: 4-5). Dauny (1992, cited in Trudeau 2013: 437), one of the most prominent New Urbanist proponents, states that the approach is modelled on the 'street-car' suburbs of the early 20th century. Fischel (2004: 5) however alludes to the street-car suburb as one where the change from rich and poor living close to where they worked had already started changing as a direct result of the introduction of the street car.

The 'Charter of the New Urbanism' (Congress for New Urbanism 1996) describes twenty-seven principles of New Urbanism. These define the vision as aspiring towards communities with features (or attributes) such as aesthetic environments that are sensitive to local values and history; higher density developments; allowing for multiple modes of transport; mixed land uses promoting pedestrian use; a focus on

civic and open spaces; multiple housing typologies encouraging diversity; and sensitivity to the environment.

It has been noted that the City Beautiful movement and Garden Cities movements of the late 19th century and early 20th century also inspire the movements' move back to focus on place making and architectural form. Criticisms of both movements are plentiful. Particularly the comprehensive planning approach embodied by these movements has been criticised for relying heavily on information driven approaches with little regard for public input. That suggests a return to rational planning. Walters (2007: 51) notes that the emphasis placed on information and intellect during the early planning days, stems from a lingering prominence and popularity of scientific information and intellect gained during the era of enlightenment. This period saw the liberation of the masses from typically "dogmatic religious faith and capricious despotism" (Walters 2007: 52) through the use of scientific information, reason and logic.

Trudeau (2013: 440-443) argues and substantiates that there have been successes and failures of New Urbanist-inspired projects. Neighbourhoods designed to encourage walking may well increase walking for utilitarian purposes, but when compared to conventional neighbourhoods, the amount of driving is not much reduced. Social cohesion in homogenous communities improves in New Urbanist neighbourhoods but does not significantly improve in heterogeneous communities. The claims of environmental sustainability as a key principle underlying New Urbanist neighbourhoods have also been drawn into question in cases. The application of the well-intentioned principles may, as with any other system, be used to reinforce exclusion based on class, race or ethnicity. Downs (1994, cited in Fischel 2004: 24) states that the mottos that follow New Urbanist practices such as 'no-growth', slow-growth' and 'managed-growth' may just be re-phrased substitutes for older means of keeping the poor out of suburbs.

All of the above theories are to a large extent based on some philosophical and ideological frame. The application of zoning ordinances is however a very practical planning task and as such may find itself at odds with the theories. It has been

suggested that planning theorists draw from ideologies rather than from empirical observation (Alexander 2015: 98) or that critique sometimes coming from academic outsiders and is not backed by empirical observations (Boyne et al. 2004: 330). There are clear frustrations that exist between the ideological aspirations of planners and what they practise. Alexander suggests that this would be "less so if planning has a pragmatic role" (Alexander 2015: 98). Zoning and GIS are practical tools used in the practice of planning. Both fields are naturally inclined to rational frameworks. That said, it should be kept in mind that the division between hard data and soft data or methods is unnecessary and counter-productive (Innes and Booher 2014: 201).

This study will operate from the premise that information is a value although not necessarily neutral (politically or otherwise); distinction must be made between empirical evidence and values but neither can be presumed to have more weight in any given context; and the better all-round, holistic information planners and citizens have throughout the planning process, the better the result must be. As Forester puts it, informing the "affected but unorganized" public earlier in the planning process is one of the suggested methods to minimise misinformation thereby providing better results (Forester 1982: 445). As for theoretical backing, because of the larger variety of popular planning theories, the approach to planning theory today is more pluralistic, realistic and flexible (LeGates and Stout 2015: 427). This study will borrow from rational planning because zoning and GIS is positivist and relates to rationality, as well as communicative planning because providing planners and citizens with a tool that is accessible and understandable is imperative in light of the need for better managed cities.

2.4 Zoning

Zoning is the legal process used by municipal authorities to control land use and development (Monmonier 1991: 72) and is typically applied to formal land parcels.

2.4.1 Overview of zoning

The history of planning in urban areas can be traced back centuries in European and Asian cities. Zoning or the rules in more-urban areas that prevent one land-owner's usage of property negatively impacting on his/her neighbours took shape in the form of 'nuisance laws' in industrialised European cities. These nuisance laws spread from

Europe, in particular Germany and England, to America during the late nineteenth century.

The late nineteenth century saw the failure of nuisance doctrine in an industrial society. The erection of the 42-storey Equitable building in Manhattan signalled the need for regulations dealing with the height and form of buildings. The 1916 Zoning Resolution of New York was passed. Later, the US Supreme Court found that the zoning ordinance of the town of Euclid was valid and use-zoning, where incompatible uses are separated, become popular (Fraietta 2012: 1926). What is important, particularly when investigating New Urbanism, is that the "un-planned" city fabric of pre-war, pre-zoning cities (American conditions between 1900 and 1920) was not restrictive, encouraged community cohesion and because of its pre-automobile state, was walkable and compact with a variety of uses within walking distances of most residences (Fischel 2004: 4-5).

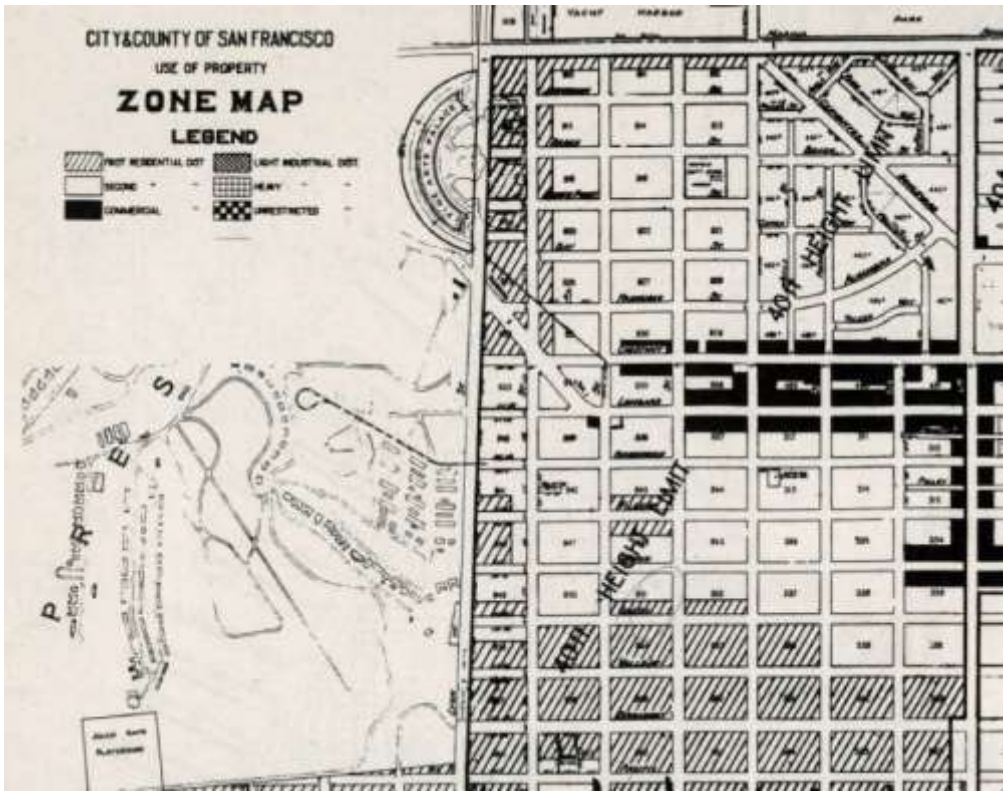
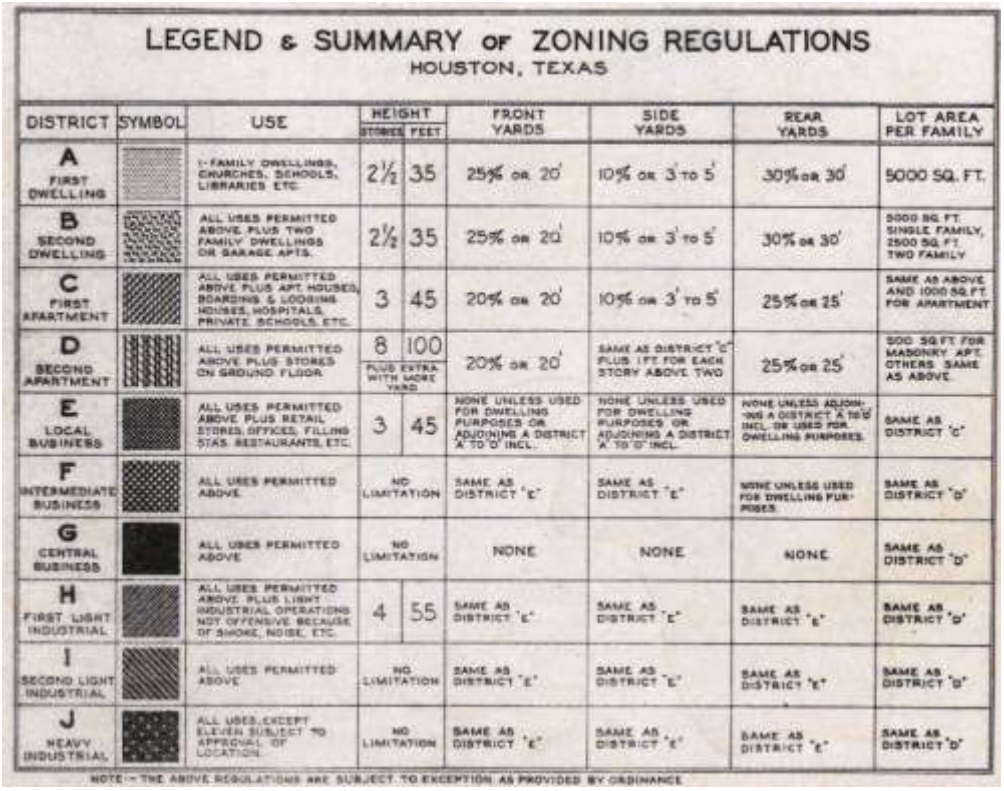


Figure 2.5: Extract of 1948 zoning map, San Francisco (David Rumsey Map Collection 2019 b)



LEGEND & SUMMARY OF ZONING REGULATIONS
HOUSTON, TEXAS

DISTRICT	SYMBOL	USE	HEIGHT STORIES	HEIGHT FEET	FRONT YARDS	SIDE YARDS	REAR YARDS	LOT AREA PER FAMILY
A FIRST DWELLING		1-FAMILY DWELLINGS, CHURCHES, SCHOOLS, LIBRARIES ETC.	2½	35	25% OR 20'	10% OR 3' TO 5'	30% OR 30'	5000 SQ. FT.
B SECOND DWELLING		ALL USES PERMITTED ABOVE PLUS TWO FAMILY DWELLINGS OR GARAGE APTS.	2½	35	25% OR 20'	10% OR 3' TO 5'	30% OR 30'	5000 SQ. FT. SINGLE FAMILY, 2500 SQ. FT. TWO FAMILY
C FIRST APARTMENT		ALL USES PERMITTED ABOVE PLUS APT. HOUSES, BOARDING & LODGING HOUSES, HOSPITALS, PRIVATE SCHOOLS, ETC.	3	45	20% OR 20'	10% OR 3' TO 5'	25% OR 25'	SAME AS ABOVE AND 1000 SQ. FT. FOR APARTMENT
D SECOND APARTMENT		ALL USES PERMITTED ABOVE PLUS STORES ON GROUND FLOOR	8 PLUS EXTRA WITH MORE YARD	100	20% OR 20'	SAME AS DISTRICT 'C' PLUS 1FT FOR EACH STORY ABOVE TWO	25% OR 25'	500 SQ FT FOR MASONRY APT. OTHERS SAME AS ABOVE
E LOCAL BUSINESS		ALL USES PERMITTED ABOVE PLUS RETAIL STORES, OFFICES, FILLING STAS. RESTAURANTS, ETC.	3	45	NONE UNLESS USED FOR DWELLING PURPOSES OR ADJOINING A DISTRICT 'A' TO 'D' INCL.	NONE UNLESS USED FOR DWELLING PURPOSES OR ADJOINING A DISTRICT 'A' TO 'D' INCL.	NONE UNLESS ADJOINING A DISTRICT 'A' TO 'D' INCL. OR USED FOR DWELLING PURPOSES.	SAME AS DISTRICT 'C'
F INTERMEDIATE BUSINESS		ALL USES PERMITTED ABOVE	NO LIMITATION		SAME AS DISTRICT 'E'	SAME AS DISTRICT 'E'	NONE UNLESS USED FOR DWELLING PURPOSES	SAME AS DISTRICT 'D'
G CENTRAL BUSINESS		ALL USES PERMITTED ABOVE	NO LIMITATION		NONE	NONE	NONE	SAME AS DISTRICT 'D'
H FIRST LIGHT INDUSTRIAL		ALL USES PERMITTED ABOVE PLUS LIGHT INDUSTRIAL OPERATIONS NOT OFFENSIVE BECAUSE OF SMOKE, NOISE, ETC.	4	55	SAME AS DISTRICT 'E'	SAME AS DISTRICT 'E'	SAME AS DISTRICT 'E'	SAME AS DISTRICT 'D'
I SECOND LIGHT INDUSTRIAL		ALL USES PERMITTED ABOVE	NO LIMITATION		SAME AS DISTRICT 'E'	SAME AS DISTRICT 'E'	SAME AS DISTRICT 'E'	SAME AS DISTRICT 'D'
J HEAVY INDUSTRIAL		ALL USES, EXCEPT ELEVEN SUBJECT TO APPROVAL OF LOCATION	NO LIMITATION		SAME AS DISTRICT 'E'	SAME AS DISTRICT 'E'	SAME AS DISTRICT 'E'	SAME AS DISTRICT 'D'

NOTE:- THE ABOVE REGULATIONS ARE SUBJECT TO EXCEPTION AS PROVIDED BY ORDINANCE

Figure 2.6: Extract showing legend and summary of 1947 regulations (David Rumsey Map Collection 2019 a)

2.4.2 Land use management systems and zoning

Land use planning is concerned with future needs and development. Typical contemporary land use planning has evolved to include designs, policies and management functions (LeGates and Stout 2015: 459). In order to understand where zoning fits in, it is useful to return to iterations popular since the mid-twentieth century. Three influential masterplan concepts have led to our practices today. Section 701 of the House Act of 1954 in the USA required local authorities to prepare comprehensive, long-range plans in order to receive grants. The Act required, amongst other things, that the plan must have a land use plan showing the location of various uses, circulation plans, public utilities plan and a community facilities plan (LeGates and Stout 2015: 451).

T. J. Kent from the University of California developed a general urban plan which included the physical and long-range planning of land uses, facility location and circulation. The plan also included policy statements and goals although no

management tools (schedules, costs or priorities). The plan was to improve the physical environment, be in the overall public interest instead of selected groups, coordinate technical and political development, and influence short-range development decisions by considering long-range plans (LeGates and Stout 2015: 451).

Stuart Chapin Jnr.'s land use plan echoed much of the Kent plan. Land use was the pivotal starting block for a comprehensive future land use plan that would guide decision making on public facility locations, zoning, sub-division control and future development patterns. Building on the Kent plan, Chapin included implementation plans (including zoning, development regulations, a housing code and sub-division control) (LeGates and Stout 2015: 453).

The above plans influenced four types of plan, or components of contemporary hybrids, common today. The land use design plan is the most direct descendant of the 1950s plans as a future-orientated land use proposal. Unlike many of the old style plans, recent versions include many environmental considerations, societal concerns arranged in themes such as economic growth, environmental functions, population and settlement growth (LeGates and Stout 2015: 454). The land classification plan is particularly influenced by Ian Mcharg's "Design with Nature" and is often applied to regions rather than small settlements. Land is classified into either development areas or non-development areas. Non-development areas are areas of ecological function or other production spaces such as agriculture, where typical urban functions are discouraged. Development areas are those where typical urban activities can be suitably and intensely clustered (LeGates and Stout 2015: 456). The verbal policy plan is typically a collection of statements and policy frameworks with little consideration for spatial patterns, and is often the first stage in developing a land use plan. Verbal policy plans are common to larger scales or higher levels of government (LeGates and Stout 2015: 456). For example, the planning system in the UK is very hierarchical. Significant power resides at the top tier of government to develop policies and macro-level plans. These policies trickle down to regional structure plans and finally local development plans (White and Allmendinger 2003: 954). The development management plan is typically a three- to five-year plan detailing existing conditions and trends, goal statements, a programme of actions and official maps. The programme

of actions forms the key portion of the plan and typically contains procedures, standards, practice requirements and programmes related to capital improvements and acquisitions (LeGates and Stout 2015: 458-459).

Contemporary hybrid plans have taken portions of the templates described above to develop holistic plans. Often referred to as the 'Package of plans' (Steenkamp 2014: 338), interrelated sets of plans act together to shape urban plans. In the eThekwini municipality, the Integrated Development Plan (IDP) is the equivalent of the verbal policy plan. The IDP is influenced by global, national and regional strategies (eThekwini Municipality 2019: 13). The Spatial Development Framework (SDF) is the embodiment of the land classification plan or land use design plans. Guided by the policy framework set out in the IDP, the SDF is the spatial manifestation of the goals of the municipality. It is meant to guide municipal decisions on land use, planning and development (eThekwini Municipality 2018: 15).

2.4.3 The objectives and purposes of zoning

The purpose of zoning can be traced back to the origins of zoning and common themes can be identified in most reiterations. Gajjar (2007: 6) informs us that the historic reasons for zoning were the prevention and spread of fire and disease and public welfare. The Standard State Zoning Enabling Act of America (1926) indicates the purpose of zoning as, amongst other things, to reduce congestion, create an environment safe from fire, panic etc., promote general welfare, ensure adequate light and air, prevent overcrowding of land and facilitate adequate provision of public requirements (Sitkowski and Ohm 2006: 167).

Most schemes today align with such objectives; for example, the Virginia Code 15.2-200 (Commonwealth of Virginia: para 1) whose purposes for zoning include: providing adequate light, air, access and safety from fire, flood and structure failure; reducing/preventing congestion; facilitating the creation of attractive and harmonious community; preserving historic areas/sites; encouraging economic development that provides desirable employment and enlarges the tax base; preserving agricultural land and the natural environment; and promoting the creation and preservation of affordable housing.

The eThekwini municipality scheme (eThekwini Municipality 2016: 7) states, amongst others, the following purposes of its scheme: implement national, provincial and municipal objectives (including the strategies set out in the city's strategic Integrated Development Plan (IDP)); manage development in order to promote public safety, health, order and general welfare, amongst other things; promote integrated and sustainable development; conserve and protect environmentally sensitive areas; and promote all forms of development and growth according to planning principles (including mixing uses in an appropriate manner). Many others have explicitly added the protection of property values.

The common theme throughout most zoning schemes is the management of development and uses in order to promote 'the general welfare' of the population of the city or town. "Welfare", being defined as "health, happiness, prosperity and well-being in general" (J.M Sinclair. 1994), is a noble pursuit even though the criticisms of zoning (and planning in general) point to abuse of the system (with inherent weaknesses) being, at least in part, responsible for the segregated, fragmented and sprawling cities of today. Related to this, the role of spatial planners is to intervene in the public interest (Alexander 2015: 98).

2.4.4 Global types of zoning

Internationally, several variations of the zoning model exist, are used or have been used. These include the following (under a variety of names):

2.4.4.1 Euclidean zoning (conventional land use management), so named after the US supreme court order that set the precedent for zoning to separate land uses in the case of Amber Realty vs. the village of Euclid, focuses on the separation of uses that are incongruent (Fraietta 2012: 1926). Typically, a formal property is assigned to a zone which is governed by a set of regulations such as density, coverage, height etc. Properties with similar uses and characteristics are grouped together and separated from those deemed to pose a health threat or nuisance to others.

The Euclidean model is perhaps the most prevalent form of zoning around the world and is the main system used in South Africa. Euclidean Zoning is widely criticised for being a main attributor to the sprawling state of cities around the world (Geller 2010:

38). Fischel (2000: 422) argues (in the case of the USA) that sprawl through suburbanisation in American cities existed long before zoning had an impact and that to believe land use controls can reverse the trend, as he phrases it, "can charitably be described as naïve." Sprawl in the South African context is different. On top of apartheid era planning which used zoning to locate large black populations on the outskirts of towns, much of the occupation on the fringes of cities occurs as a result of immigrants to the city settling on the edge. This occurs in areas considered affordable and where formal authorities have to date not ventured (Watson 2009: 176).

Zoning of all forms have been or could be used to promote exclusionary development (Watson 2009: 176; Nel 2015: 83). In the South African context zoning and comprehensive planning was used during the colonial and apartheid eras to segregate and exclude black races under the guise of scientific reason (Scott 2003: 240). Furthermore, many of the contemporary conservation regulations in schemes have been highlighted as being potentially exclusionary.

It is also clear from several sources (Fischel 2000: 407; Scott 2003: 250; Watson 2009) that zoning is controlled, to a large degree, by politics and power, which have and can be used to promote agendas at the expense of some. In South Africa's past this has been devastating and the risk of abuse of political power through zoning remains real. Zoning and development control in the USA and UK have a greater impact on property values than fiscal controls, strategies, public plans or coalition building (White and Allmendinger 2003: 955). There is no guarantee against manipulation in planning (Forester 1982: 444).

Arguments around whether zoning excludes by 'housing-affordability' also exist. On the one hand, part of the purpose of the scheme is the protection of property values. Within homogenous zones, proximity to non-conforming uses have shown to decrease property values (Fischel 2000: 409). On the other hand, the exclusion of poorer classes by higher property values has detrimental effects which include sprawl, sustained poverty and informality.

Euclidean zoning, in particular, is criticised for being rigid or inflexible. A growing body of work suggests that more mixed uses have significant impacts on travel/

commuting patterns in urban environments (Bordoloi, Mote, Sarkar and Mallikarjuna 2013: 572; Cooke and Behrens 2014: 70). Evidence suggests that a one-size-fits-all approach does not work and that new developments, or in the South African case, new zoning areas, and established and mature areas need differential treatment (Elliott 2012: 130). The regulations accompanying conventional zoning could be confusing and easily misinterpreted (Gajjar 2007: 14; Moroni and Lorini 2016: 6).

2.4.4.2 Flexible conventional zoning, including incentivised zoning, is a variation of Euclidean zoning which allows for special zones within the typical scheme in order to promote particular local, provincial and national objectives. In these areas, the typical regulation of development and use are generally adjusted or relaxed or applied differently to accommodate another need. Most of the schemes in operation today are hybrid schemes that draw on the experience of the past hundred years (Elliott 2012: 129), although most still rely on Euclidean zoning as backstop (Elliott 2012: 130).

The criticisms of flexible zoning are similar to that of Euclidean zoning. Durban (the eThekwini Municipality) typically has a flexible Euclidean zoning approach with large homogenous areas and several 'special zones' to promote various agendas.

2.4.4.3 Form-based zoning (contemporary zoning) essentially focuses on building typology and its interactions with the public realm rather than land or building use. Land use however is implicit in the allowable building typologies (Sitkowski and Ohm 2006: 167).

Form-based zoning, being one of the practical models of New Urbanist ideals, is meant to create a predictable outcome, firstly, of the physical form of a neighbourhood and secondly of the land use of the neighbourhood (Gajjar 2007: 28). This is accomplished through regulations that are set out in the various components of form-based zoning. Some of the regulations include lot shape and size; building placement; setback lines; frontage type; density; building heights (main and ancillary); parking location; parking numbers; building use; and civic spaces. (Gajjar 2007: 69).

2.4.4.4 Performance based zoning focuses less on the actual 'land use' and more on the externalities and nuisances caused by use (Nel 2015: 80). The system, which found

some traction in the late 1980s and early 1990s, theoretical appropriateness or superiority apart, has lost favour mainly because of the high level of technical expertise required to regulate and manage activity. Presently some components of this approach have been incorporated in some schemes (notable the New York City zoning scheme) and with technological advances occurring at an unprecedented rate, it is entirely possible that the performance-based approach may again gain favour in the near future.

2.4.4.5 Restrictive conditions and covenants are typically older forms of land use control, some of which still exist in South Africa in areas previously not under schemes as well as in new estate developments. While these were successful in the early 20th century, they are less transparent than what current practice demands. Covenants today can further prohibit certain activities which may be permitted with the zoning of a property but they cannot allow uses prohibited by the zoning (Fischel 2000: 410).

2.4.4.6 The English discretionary system is a system in which every new development or change is vetted by officials. This creates concerns about consistency and requires high levels and large capacity of technical skills (Nel 2016: 261). The planning system in the UK is very hierarchical. Significant power resides at the top tier of government to develop policies and macro-level plans. These policies trickle down to regional structure plans and finally to local development plans (White and Allmendinger 2003: 954). In the UK, local planning authorities have significant autonomy to interpret the policy framework (White and Allmendinger 2003: 954).

2.4.4.7 No zoning: Some mention should be made of urban areas that have elected not to employ zoning as a tool for land use management. These are few but the city of Houston in America is one such example. While there is no zoning, private covenants are employed to regulate development and the net result is similar land use patterns as zoned cities (Fischel 2000: 410).

2.4.5 Components of a typical scheme

The above information was provided as a brief overview of zoning. Of particular concern to this study however, are the typical components of schemes. Two documents reviewed explicitly detail the components in the South African context. The

Guidelines for the preparation of schemes for municipalities by The Planning Initiative team (Briginshaw, D. M., Kahn, M., Ferguson, C. A. C. 2011) and a recent report suggesting a scheme framework for Durban by IYER Design Studio (Iyer Design Studio 2012) indicate the essential components as:

a) The Zoning Map, which is a spatial representation of land parcels within zones across the regulated areas of a city or town. The zones or zoned properties are typically shown as unique values on a map using different colours, hatches and annotation to denote the different zones.

b) The Scheme Regulations document typically contains an overview of the aims and objectives of the scheme, the legislative framework in which the scheme operates and, of particular interest to this study, the zone regulations. Typically minimum lot size, use permissions (assigned use; use via special consent and precluded uses), setback lines (and side and rear space), coverage and floor area ratios are stipulated (Briginshaw, D. M., Kahn, M., Ferguson, C. A. C. 2011: 34). As has been mentioned above, the various iterations of schemes to accommodate new approaches mean that some municipal schemes include additional regulations such as performance-based regulations and building shape regulations. Zoning regulations are multi-faceted. Urban economist models found that no one constraint value can be added to their model to represent zoning regulations (Fischel 2000: 406).

c) Procedures. These relate to Applications (Approvals and Appeals), Review, Management, and Monitoring of development as it relates to land usage within the city. It should be noted that most processes involve a wide variety of departments or sections from the Internet map and 'front-desk', where initial queries regarding property zoning are made to the town planning appeals board.

d) The Definitions or Glossary provided with most schemes as an attempt to inform and reduce misinterpretation of terms and jargon. Normally these are included in the regulations document.

e) People. A wide variety of people use, benefit or are otherwise affected by zoning. Citizens or the public are regulated in terms of what activities may be undertaken on land within the jurisdiction of a scheme. They benefit from this regulation by enjoying relatively safe, organised and stable environments. The public may also be victims of the abuse of the system. City officials enforce the code and benefit from normative procedures and the efficiency systems are meant to enhance. Researchers, consultants

and other stakeholders use zoning information for a variety of applications and as proxies for other data.

The zoning map, which is one of the key components of the scheme, is a spatial representation of legally defined properties. A core functionality of a GIS is the spatial representation of land features. In this case, legally defined land forms that rely heavily on absolute measurements of location (land areas defined by boundaries that connect precision-surveyed beacons).It is noted that this reliance is one of the criticisms levelled at GIS.

The colours/hatches/annotation on a zoning map (either zones or properties themselves) denote the zone in which a property falls. Each zone is ascribed a set of rights and regulations which in turn is bestowed on each property in that zone (or with those characteristics). GIS differentiates itself from CADD as it is able to link the geometric representation of a land feature with a database that can store nearly any attribute of that object. In other words, a property (the geometry) can be linked to any attribute of that property (area, description, zoning, land use, owner and more.)

The procedures within the regulations of a scheme are set out within a legal framework and demand strict adherence, transparency and validity (because of the legal nature of the framework and the potential repercussions of deviation). GIS, often criticised for being positivist, also require strict adherence to protocols and standards if the data acquired are to be trusted, the analysis results trusted or the outputs interpreted correctly. Many of these processes and procedures overlap and act symbiotically.

The users of both zoning schemes and GIS are typically professionals involved in the built environment. The beneficiaries of schemes are the citizens of a city or town and increasingly, the beneficiaries of GIS technology (whether they realise it or not) are members of the public through the Internet or through smartphone applications.

2.4.6 Components of a form-based zoning plan

The components of a form-based zoning (FBZ) plan are similar to those of conventional schemes at first glance. These include:

a) *The regulating plan* is the upfront, community-developed plan designating areas of use (even though FBZ claims less emphasis on it), building typology and zones. Both Gajjar (2007: 37) and Sitkowski and Ohm (2006: 164) indicate that the regulating plan resembles a zoning map but is more detailed in that it also provides details on building location and typologies, street types and other design criteria related to the public realm. Interestingly, Bardette (2004, cited in Gajjar 2007) states that zoning plans have too many categories which seem contradictory, considering the above-mentioned level of detail on the regulating plan. An important characteristic of the regulating plan is that it is developed along with the prospective community. One of the criticisms of FBZ is that this, often complicated, approach is costly and requires a lot of time.

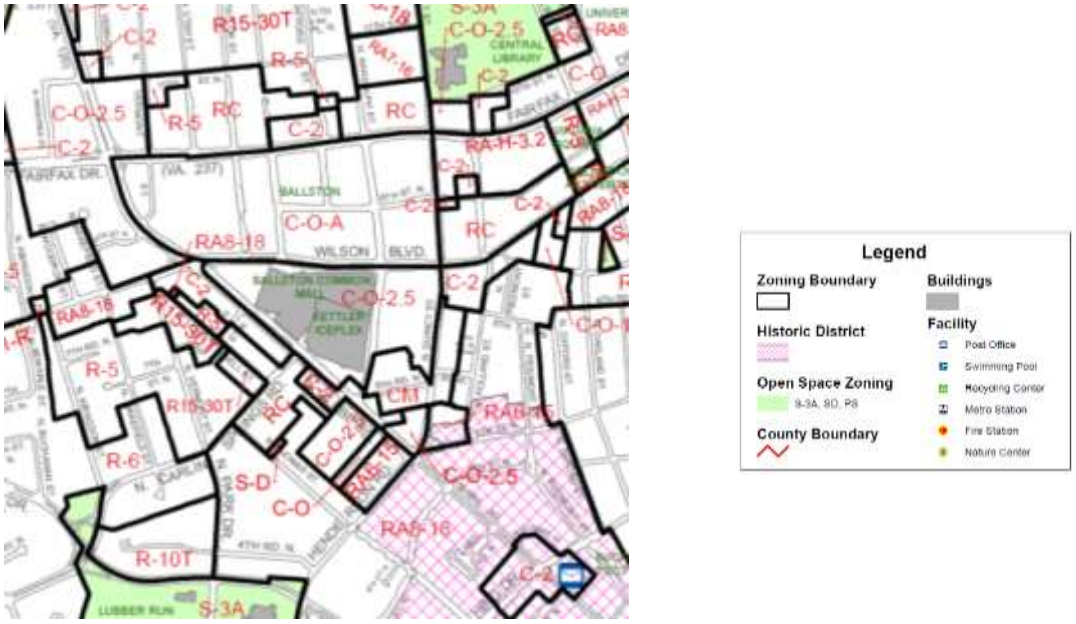
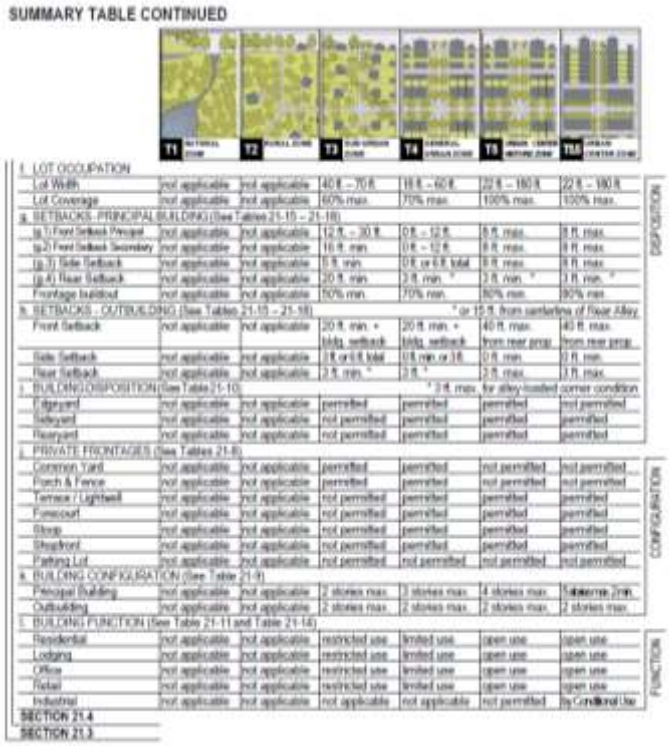


Figure 2.7: Regulating plan (Arlington FBC, City Mapping Center 2020)

b) *Building form standards.* Gajjar (2007) highlights some of the regulations regarding the configuration, features, and functions of buildings in FBZ. While the detail seems similar to conventional zoning regulations (number of floors, setbacks etc.) the detail increases to include minimum and maximum heights (to fit in and contribute to developing street character), siting and the location of parking (so as not to interfere with the street character). Although not mentioned here, several other texts include 'build-to', lines which again attempt to create particular characteristics in the public realm. Both Gajjar (2007) and Sitkowski-and-Ohm (2006: 167) explicitly state that building use

is also specified although Sitkowski and Ohm terms it “in-building use standards”.


SUMMARY TABLE CONTINUED

	T1	T2	T3	T4	T5	T5A
A. LOT OCCUPATION						
Lot Width	not applicable	not applicable	40 ft. – 70 ft.	16 ft. – 60 ft.	22 ft. – 180 ft.	22 ft. – 180 ft.
Lot Coverage	not applicable	not applicable	60% max.	70% max.	100% max.	100% max.
B. SETBACKS - PRINCIPAL BUILDING (See Tables 21-15 – 21-18)						
(g.1) Front Setback Principal	not applicable	not applicable	12 ft. – 30 ft.	0 ft. – 12 ft.	8 ft. max.	8 ft. max.
(g.2) Front Setback Secondary	not applicable	not applicable	16 ft. min.	0 ft. – 12 ft.	8 ft. max.	8 ft. max.
(g.3) Side Setback	not applicable	not applicable	5 ft. min.	0 ft. or 6 ft. total	8 ft. max.	8 ft. max.
(g.4) Rear Setback	not applicable	not applicable	20 ft. min.	3 ft. min. *	3 ft. min. *	3 ft. min. *
Frontage buildout	not applicable	not applicable	50% min.	70% min.	80% min.	80% min.
C. SETBACKS - OUTBUILDING (See Tables 21-15 – 21-18)						* or 15 ft. from centerline of Rear Alley
Front Setback	not applicable	not applicable	20 ft. min. + bldg. setback	20 ft. min. + bldg. setback	40 ft. max. from rear prop.	40 ft. max. from rear prop.
Side Setback	not applicable	not applicable	3 ft. or 6 ft. total	0 ft. min. or 3 ft.	0 ft. min.	0 ft. min.
Rear Setback	not applicable	not applicable	3 ft. min. *	3 ft. *	3 ft. max.	3 ft. max.
D. BUILDING DISPOSITION (See Table 21-10)						* 3 ft. max. for alley-loaded corner condition
Edgeyard	not applicable	not applicable	permitted	permitted	permitted	not permitted
Sideyard	not applicable	not applicable	not permitted	permitted	permitted	permitted
Rearyard	not applicable	not applicable	not permitted	permitted	permitted	permitted
E. PRIVATE FRONTAGES (See Tables 21-8)						
Common Yard	not applicable	not applicable	permitted	permitted	not permitted	not permitted
Porch & Fence	not applicable	not applicable	permitted	permitted	not permitted	not permitted
Terrace / Lightwell	not applicable	not applicable	not permitted	permitted	permitted	permitted
Forecourt	not applicable	not applicable	not permitted	permitted	permitted	permitted
Stoop	not applicable	not applicable	not permitted	permitted	permitted	permitted
Shopfront	not applicable	not applicable	not permitted	permitted	permitted	permitted
Parking Lot	not applicable	not applicable	not permitted	not permitted	not permitted	not permitted
A. BUILDING CONFIGURATION (See Table 21-9)						
Principal Building	not applicable	not applicable	2 stories max.	3 stories max.	4 stories max.	5 stories max.
Outbuilding	not applicable	not applicable	2 stories max.	2 stories max.	2 stories max.	2 stories max.
B. BUILDING FUNCTION (See Table 21-11 and Table 21-14)						
Residential	not applicable	not applicable	restricted use	limited use	open use	open use
Lodging	not applicable	not applicable	restricted use	limited use	open use	open use
Office	not applicable	not applicable	restricted use	limited use	open use	open use
Retail	not applicable	not applicable	restricted use	limited use	open use	open use
Industrial	not applicable	not applicable	not applicable	not applicable	not permitted	by Conditional Use
SECTION 21.4						
SECTION 21.3						

Figure 2.8: Bellevue FBC, property standards summary (City of Bellevue Kentucky 2018: 165)

c) *Public realm or street standards* deal with elements within the public realm. There is considerable road design in FBZ. Geller (2010: 64-65) provides a brief statistic about the effect of modern rounded intersection corners and the direct correlation this has on pedestrian deaths in the US annually. FBZ, SmartCode and other New Urbanist models attempt to change this by stipulating allowable turning radii appropriate to the development. Furthermore, street furniture placements, tree positions, sidewalks, curb-heights on so forth are regulated. Of importance also is the regular stipulation of on-street parking (as opposed to on-site parking). Widths and scale of roads are regulated to be appropriate for the envisaged character and scale of the streetscape.

Table 2.8 Street Assembly Summary

Abbreviation	BVC	BL / RA	RR	GR	OA	ND - A2	ND - A6	MS
Street Type	Bikeway / Carkway	Rear Lane Rear Alley	Rural Road	Greenway	Oak Allee	Neighbor-hood Drive	Neighbor-hood Drive	Main Street
Frontage Type	Island Thorough-fare	N/A	Road	Island Thorough-fare	Island Thorough-fare	Street, Scenic Street	Street, Scenic Street	Avenue, Scenic Avenue
Transect Zone	D1, D2, D3, D4, PD, D5	D1, D2, D3, D4, PD, D5	D1, D2,	D1, D2, D3, D4, PD	D1, D2, D3, D4, PD	D3	D4, PD, D5	D4, PD, D5
ROW Width	22 ft.	22 ft.	36 ft.	42 ft. plus min. 66 ft. of dedicated greenway per side	42 ft. plus min. 65 ft. of buffer for Oaks per side.	42 ft.	46 ft.	60 ft.
Pavement Width	12 ft.	12 ft.	18 ft.	22 ft.	22 ft.	22 ft.	22 ft.	30 ft.
Surfacing	LINU and Asphalt	LINU	LINU and Asphalt	LINU and Asphalt	LINU	LINU	LINU	LINU
Movement	Yield	Yield	Slow	Slow	Slow	Slow	Slow	Slow
Design Speed	10 mph	10 mph	20 mph	20 mph	20 mph	20 mph	20 mph	20 mph
Pedestrian Crossing Time	3.5 sec.	3.5 sec.	5.1 sec.	6.0 sec.	6.0 sec.	6.0 sec.	6.0 sec.	7.9 sec.
Traffic Lanes	N/A	N/A	2 lanes	2 lanes	2 lanes	2 lanes	2 lanes	2 lanes
Car Parking Lanes	None	None	None	None	None	None	None	Car-one side @ 8 ft. marked
Cart Parking Lanes	None	None	None	None	None	Cart-one side @ 7 ft. marked	Cart-one side @ 7 ft. marked	Both sides angled at 8 ft. marked
Curb Radius	N/A	Taper	10-30 ft.	10-30 ft.	10-30 ft.	0-20 ft.	0-20 ft.	0-20 ft.
Walkway Type	N/A	None	Path (No Path – By Waiver)	Path (No Path – By Waiver)	Path (No Path – By Waiver)	Min. 5 foot Sidewalk or Path	Min. 5 foot Sidewalk	Min 6 foot Sidewalk Max 9 foot Sidewalk
Planter Type	N/A	None	Continuous Swale	Continuous Swale	Continuous Swale	4 foot Continuous Swale or Planter	4 foot Continuous Planter	3 foot Continuous Planter
Curb Type	LINU	Inverted crown	Swale	Swale	Swale	Raised Curb or Swale	Raised Curb	Raised Curb
Landscape Type	Clustered	None	Clustered	Clustered	Regular at 30' on center avg.	Regular at 30' on center avg.	Regular at 30' on center avg.	Regular at 30' on center avg.
Canopy*	Full	Minimal	Partial to Enclosed	Partial to Full	Enclosed	Partial to Full (one side)	Partial to Full (one side)	Minimal to Partial (one side)

Figure 2.9: Daufuskie Island Code, Street Assembly summary regulations (Beaufort County Council 2016: 50)

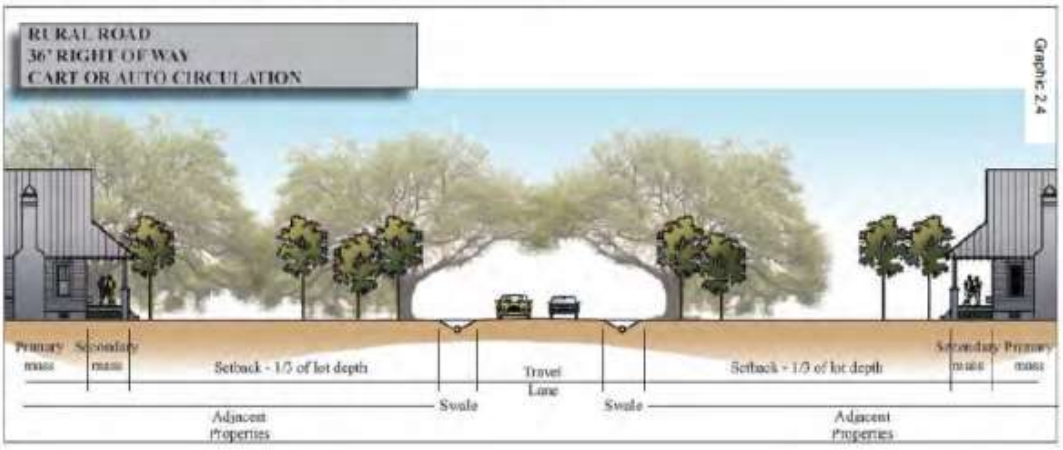


Figure 2.10: Daufuskie Island FBC Road regulations sample (Beaufort County Council 2016: 43)

d) Administration: This component includes processes dealing with the legalisation of FBZ, development applications, approvals, appeals etc. One of the key constraints to the implementation of FBZ as a tool for the management of urban land is the existing legal framework. Many municipalities have adopted a hybrid approach to include FBZ standards in existing schemes. Because there is an overlap in the general objectives of FBZ and conventional

zoning, Sitkowski and Ohm (2006: 83), amongst others, state that FBZ can be incorporated into a 'comprehensive plan'. Gajjar (2007: 90) recommends that FBZ be simplified and incorporated into existing schemes. She concludes by stating that, "New methods should be developed within FBZ to integrate simplified regulations, physical design and land use, and technology for shaping the public realm in a meaningful built environment in comprehensive manner" (Gajjar 2007: 92).

e) Definitions. A glossary clearly defining terms is provided with the regulations to avert confusion or misinterpretation.

As with a zoning plan, the regulating plan is a spatial representation of parcels and zones within a study area or town. One of the key strengths of GIS is the spatial representation of physical features (including administrative and legal boundaries).
As with conventional zoning, FBZ assigns regulations to zones (whether they be transect zones or typology zones) and the properties that fall within those zones.

Also, as with conventional zoning, albeit in a diagrammatic format, the majority of regulations are separated from the plan. GIS, as already explained, offers the ability to link these regulations and rights to the property within a single database. New technological advances in contemporary database structures also mean that the graphical regulations pertaining to zones may be stored within the same database (ESRI 2020a). The fact is that much of the detailed planning happens during the development of the regulating plan (which typically occurs on greenfield or infill sites), which implies that many of the regulations could be implemented spatially (and represented spatially) before development occurs.

Since the processes in FBZ and GIS both deal with spatial objects and their attributes, these procedures should align in order to provide an efficient, accurate service. The strict nature of GIS method documentation aids in the transparent process required.

Typically, the users of form-based zoning and GIS are professionals assigned to deal with planning or spatial matters. The planning (including acquiring base data, disseminating information to the community, visualising alternatives etc.), implementation and management of the system require similar skillsets in both fields.

The beneficiaries of both systems are the public/community as well as officials who gain by having better informed plans and systems.

2.4.7 South African legal framework

While the Guidelines for the preparation of schemes for municipalities (Briginshaw, D. M., Kahn, M., Ferguson, C. A. C. 2011) highlight several Acts that impact the use of zoning in the province of Kwazulu-Natal, this study reviewed those that were considered to be most relevant to this topic.

The Constitution of the Republic of South Africa, 1996, came into being after apartheid. Its main purpose is the protection of all the people of South Africa. Several parts of the Constitution deal with items of relevance to this study. In Chapter 7, section 152 (1), (Republic of South Africa 1996: 74) the articles dealing with local governance state the following local government objectives:

c) To promote social and economic development;
d) Promote a safe and healthy environment; and
e) Encourage the involvement of communities in the matters of local government.

All of the above objectives strongly align with the objectives of a typical zoning scheme. Chapter 7 section 156 (2) also specifies that one of the powers and functions of a local government is that it:

> May make and administer by-laws for effective and efficient administration of matters it has the right to administer (Republic of South Africa 1996: 76).

This effectively makes it a constitutional prerogative of municipalities not only to make the scheme laws, but also to apply them in an "effective and efficient" manner. Chapter 7, section 162 (3) indicates that the municipal by-laws must be accessible to the public.

Accessibility to laws regarding the citizenry is a key right in a democratic nation. Levels of accessibility at present are questionable. As is the case with zoning, any citizen may go through the process of driving to a municipality, waiting in line, seeing a clerk, who then has to find the regulations pertaining to the citizen's property, and finally has to interpret the meaning for the citizen.

Chapter 10 of the Constitution deals with Public Administration and states, as part of the basic values and principles governing public administration (section 195), that:

- A high standard of professional ethics must be promoted and maintained.
- Efficient, economic and effective use of resources must be promoted.
- Services must be provided impartially, fairly, equitably and without bias.
- Transparency must be fostered by providing the public with timely, accessible and accurate information (South Africa 1996: 99).

Again, these objectives highlight a need for a system that is efficient, reduces the threat of bias through the use of systems that remove subjective interpretation, and is accessible in broadest sense of the word.

Scott (2003: 248) refers to the provincial Townships and Town Planning Ordinance of 1934 as being the first legislative framework for zoning in Natal. The purpose of the Ordinance was "managed development" through the zoning component of masterplans to ensure, amongst other things, general welfare, safety, order, amenity and economic development. The Town Planning Ordinance 27 of 1949 replaced the Ordinance of 1934 and was used until early 2000 when repealed and replaced by the Development Facilitation Act 67 of 1995. Ordinance 27 of 1949 (SouthAfrica 1949: 51) echoed the objectives of the 1934 Ordinance and was used for half a century to shape and manage development of urban areas in Natal.

Since the end of the apartheid era (1994) several planning-related Acts (such as the Kwazulu-Natal Planning Development Act 06 of 2008, the Development Facilitation Act 67 of 1995 and more) have attempted to redress the imbalanced development of South African cities and society.

The Spatial Land Use Management Act, No 16 of 2013 (Republic of South Africa 2013), also known as SPLUMA, is the first "cohesive spatial planning and management system for the entire country" (Nel 2015: 80). While it applies to all spheres of government, its applicability is particularly appropriate at local government levels.

This Act defines the objectives of a scheme in order to promote:

a) economic growth
b) social inclusion
c) efficient land development
d) minimal impact on public health, the environment and natural resources (Republic of South Africa 2013: 36).

These objectives resonate to some extent with traditional objectives of town planning schemes. A notable shift from the objectives of schemes occurs in the apparent promotion of the importance of economic growth and social inclusion and the demotion of public health, order and sustainability.

SPLUMA further specifies that any scheme must have a map and regulatory documents regarding zones as well as a register of changes to schemes (South Africa. 2013: 36). It does not however make any mention of GIS or how GIS might be deployed in the development of the required schemes.

Perhaps the most far-reaching impact of this Act is the proclamation that within five years of the adoption of the Act, all municipalities must have a single zoning plan for their entire jurisdiction (South Africa 2013: 31). For a municipality like eThekwini, that implies consolidating more than 20 existing suburb schemes and increasing the zoned extent from 85 390ha to 229 193ha.

Despite the documented criticisms of zoning and the good intentions of SPLUMA, Nel (Nel 2015: 83-84) points out that the use of conventional zoning is in many ways contradictory to the principles underlying SPLUMA. She notes that form-based zoning, in her opinion, could have been an alternative to conventional zoning but that the capacity and skills required are lacking in most municipalities (Nel 2015: 87-88).

2.5 Conclusion

Monmonier suggests that maps are “indispensable exhibits” in legal cases regarding the use of land or control of development (Monmonier 1991: 77). Recent trends suggest that GIS maps and databases and web applications are the tools that will

provide the citizenry of the future with the information regarding their property rights and the regulations related to these.

The New Urban Agenda (United Nations, Habitat 2017: 28) which was adopted in October 2016 by government representatives and planners from around the world, at the UN Habitat Conference aims, amongst other things, to:

> …promote the development of **adequate and enforceable regulations** in the housing sector, including, as applicable, **resilient building codes, standards, development permits, land use by-laws and ordinances**, and **planning regulations, combating and preventing speculation**, displacement, homelessness, and arbitrary forced evictions, ensuring sustainability, quality, affordability, **health, safety**, accessibility, energy and resource efficiency, and resilience. We will also promote differentiated analysis of housing supply and demand based on high-quality, timely, and reliable disaggregated data at the national, sub-national, and local levels, considering specific social, economic, environmental, and cultural dimensions" (bold added by author).

The above statement of intent echoes those intentions in South Africa's SPLUMA to extend zoning in order to advance general public welfare. These extensions will require more efficient and effective approaches from those that have been undertaken to date.

In the field of spatial planning and the legislation that surrounds it, the concept of space is dominant and omnipresent. This has led drafters of spatial legislation to move from the textual descriptions in standard law to becoming adept at making good maps (Boer, Van Engers, Peters and Winkels 2007: 51). Boer suggests that there are several reasons why some regulations are naturally suited for display on maps. These include presentation and the comfort of citizens (Dutch in his case) with maps, territorial jurisdiction, adjacency and the fact that certain regulations can naturally be grouped by area, transparency of metadata where a spatial reference is much more meaningful than obscure descriptions, and citizen-centred organisation of data, implying a user interface that serves the citizenry more than legislators (Boer et al. 2007: 52-53). Boer (Boer et al. 2007: 54) states that:

> The Dutch Government programme leaders think that maps are relevant for the national search portal to inform citizens about rules and regulations of local governments in a way that makes sense to them.

The above statement resonates not only with transparent governance but very much also with the principles of communicative planning where divulging information pertaining to citizen rights on a grand scale may lead to changes in the behaviour of the citizenry (Bolton 2005: 2).

Before the validity claims in Habermas's communicative action theory can be tested in an act of communication, there needs to be comprehensibility (Ross and Chiasson 2011: 125). Accessibility could be added since it is known that zoning regulations can be confusing and easily misread (Moroni and Lorini 2016: 6), and are kept separate from the zoning map. Zoning systems have become more complex and as such departments dealing with zoning require more specialised skills (Elliott 2012: 130) to effectively communicate zoning regulations in ways that minimise technocratic jargon, build public trust, avoid manipulation and provide information that is accurate (Forester 1982: 444). Effectively, quantum leaps in efficiency are required, which are available when using the Internet, web-based applications (Elliott 2012: 130) and databases.

Public choice theory suggests that those employed to act in the public interest may in fact be self-interest maximisers (Fraietta 2012: 1939). Combined with a rationally ignorant public, the need for changes to the zoning system to promote transparency and accuracy is clear. Progressive planners believe that most instances of misinformation are not accidental and that here is a need for planners to anticipate the way in which misinformation occurs so that corrective measures may be taken (Forester 1982: 441, 445).

Foucalt suggests that dealing with power, including that wielded by zoning administrators, cannot be ignored but should be dealt with by being strategically in conflict with power (Flyvbjerg et al. 2002: 54-55). Changing the status quo to a system that is openly strategic and where the information is interactive, queriable and

connected to other data sources may be disruptive and may be in line with Harley's objectives to combat internal and external biases in maps (Crampton 2001: 244).

Graphic norms are standards or laws depicted in graphic rather that textual format. Moroni and Lorini (2016) recognise that the study of "graphic norms seem(s) to be an original topic" (Moroni and Lorini 2016: 2) and that the occurrence of such norms is more common than typically recognised (Moroni and Lorini 2016: 3). The study of such norms is important in particular for planning practice. While they mention several cases in US law where the map and not the accompanying text regulations were used as the deciding factor, they also argue that graphic norms and textual norms are not mutually exclusive. Graphic rules however are rules and are not subsidiary to text regulations (Moroni and Lorini 2016: 14).

The typical normative maps of a zoning scheme (including form-based codes) already contain three types of graphic rules. These are constitutive, regulative and technical rules (Moroni and Lorini 2016: 8-9). These rules are treated differently and symbolised differently on maps. Moroni and Lorini go further than Boer in explicitly stating some of the potential geometric representation of laws, but fail to apply the principles. They do however conclude that the study of graphic rules requires significantly more effort particularly in light of GIS technology, and that filling the gap seems a "valuable enterprise, not only for purely theoretical reasons" (Moroni and Lorini 2016: 15).

The nature of land parcels and zoning regulations naturally lends itself to the object-orientated approach of the vector model. This does not imply that raster data will not be useful in the model that this study will propose, since images are rasters and may prove vital additions.

Chapter 3. International and local precedents in GIS representation of zoning

3.1 Introduction

In order to determine whether GIS is appropriate for the representation of development regulations in conventional and alternative schemes, it was necessary to investigate international and local precedents in terms of how cities around the world represent zoning and disseminate information about zoning to their respective citizens. Six cities were randomly chosen from around the world to serve as sample cities.

It should be noted that some bias exists in the sample since English speaking cities had to be chosen in order for the author to be able to interpret the data. The choice of English speaking cities implies that the cities or countries were likely to have been English colonies and hence would have been influenced by the English system.

The sample cities include New York City (USA), London (Canada), Dublin (Ireland), Hong Kong (China), Christchurch (New Zealand) and Cape Town (South Africa). A single zone from each ordinance was chosen for investigation and attempts were made to use similar zones in the various cities.

Notwithstanding the bias towards English systems, an attempt was made to spread the choice of sample cities geographically around the globe. New York City in North America was chosen since it has one of the longest-existing zoning schemes in the modern format. London in Canada was chosen by mistake. Initial investigations of the web-map resembled what the author expected to find in London, England (including geographic names and the zoning system). It wasn't until much later that the location was revealed to be in Canada. Regardless, the city was included as a good example of parcel-based zoning. Dublin, in Ireland, was chosen for the variety of ways in which zoning information was made available. Several searches into African systems were made but limited detail for most of the cities on the continent swayed the research back to South Africa and Cape Town. Hong Kong, as an English system, was the only possible choice in Asia. Initial attempts in respect of Australian cities, which often

post detailed GIS data on the Internet, were met with interruptions. Christchurch was chosen as a working, stable and appropriately detailed alternative.

Figure 3.1 Location of sample cities (by author)

3.2 New York City, United States of America

New York City is arguably one of the oldest proponents of zoning as it is in its current form, having accepted zoning as legitimate through the Zoning Resolution of 1916 (Fraietta 2012: 1926). The type of zoning is Euclidean and rather than using parcels to zone, the city uses districts (New York City Planning 2019a). Variations within the districts is accommodated by using overlay zones (New York City Planning 2019b). The city has a website dedicated to zoning and land use named ZoLa. Land use separation is evident from the map and there are five main zones: commercial, manufacturing, residential, parks and Battery Park City (New York City Planning 2019a).

Figure 3.2 New York City: Showing the Euclidean zoning approach (New York City Planning 2019a)

Figure 3.3 New York City: Showing the use of districts and overlay zones (New York City Planning 2019b)

The dynamic web-map shows zoning descriptions in the legend and coded labels on the map. The various zones are denoted with different colour symbols. The link between the coded labels and zoning descriptions are made easily since the initial of the various zones are used for the label.

Apart from the zoning layer, overlay zones and many other contextual layers are on the map. The additional layers include zoning map amendments, pending zoning map amendments, special purpose districts, inclusionary housing designated areas, limited height districts, tax lots and environmental designations. In total there are 38 layers of information available to the public on the map (New York City Planning 2019a).

As is expected from this style of zoning, the scheme is comprised of two main parts: the map and the regulation document. What is interesting is the intermediate pages that are accessible from a link on the map which describe the bulk regulations of the zone in colloquial terms and graphically (see (New York City Planning 2019f). From the intermediate page, the full zoning resolution can be accessed.

The "R5A Low Density Contextual Residence District" zone regulations were inspected for further insight. The R5A zone contains four variations within the zone, "use groups" 1 to 4. Within each, slight variations exist, allowing for more or less activities related to residential activities. The permitted uses accommodate around seven residential typologies ranging from "Single detached housing" to "Student dormitories". The "accessory uses" which accompany each use group allow uses that complement residential uses (New York City Planning 2019e: Chapter 2: para 22-10).

The use regulations and bulk regulations for the R5A district are contained in around 35 pages which are navigated with relative ease. Exceptions to the rule complicate the regulations. For example, use group 4 allows for club activities except if the service is mainly commercial or if it is a swimming pool club where the pool is closer than 500 feet from a lot line or the club is an adult physical culture establishment (New York City Planning 2019e: Chapter 2: 22-14).

Figure 3.4: New York City: Showing direct links to regulations (New York City Planning 2019c)

The controls used by the scheme include several typical types. Floor area ratios (New York City Planning 2019e: Chapter 3: 23-142), coverage (New York City Planning 2019e: Chapter 3: 23-142), building height (New York City Planning 2019e: Chapter 3: 23-63), setback lines (New York City Planning 2019e: Chapter 3: 23-63), building lines (New York City Planning 2019e: Chapter 3: 23-711), site size (New York City Planning 2019e: Chapter 3: 23-32), wall heights (New York City Planning 2019e) and parking requirements (New York City Planning 2019e: Chapter 5: 25-22).

Furthermore, a dwelling unit factor, planting strips, and obstructions permitted in open space are among additional controls. None of the regulations are depicted on the web-map either graphically or as attributes to the map features.

3.3 City of London, Canada

The city of London in Canada uses Euclidean zoning to manage its land use. Zoning information is made public through a dynamic web-map dedicated to planning and zoning related information. The zones are shown on the map as a single symbol outline with coded labels. The style of representation makes it difficult to see the separation of land uses. At first glance, it appears that districts are used to apply zones but when each parcel is interrogated, it becomes clear that zoning occurs at parcel level and the apparent districts are cartographic generalisations.

For the purpose of this study, the Residential R1 zone was investigated. Apart from the coded zoning name, the parking standard regulation is also shown on the map in the form of a labelled polygon outline. No other regulations are shown graphically.

The regulations pertaining to each parcel can be accessed from the map by clicking on a particular parcel and following the link on the attribute dialog box. Zoning information is not on the first page of the dialog box. Unlike the case of New York City, there is no public-friendly intermediate page or opportunity to see the entire regulations document. Instead, only the regulations pertaining to queried property are opened.

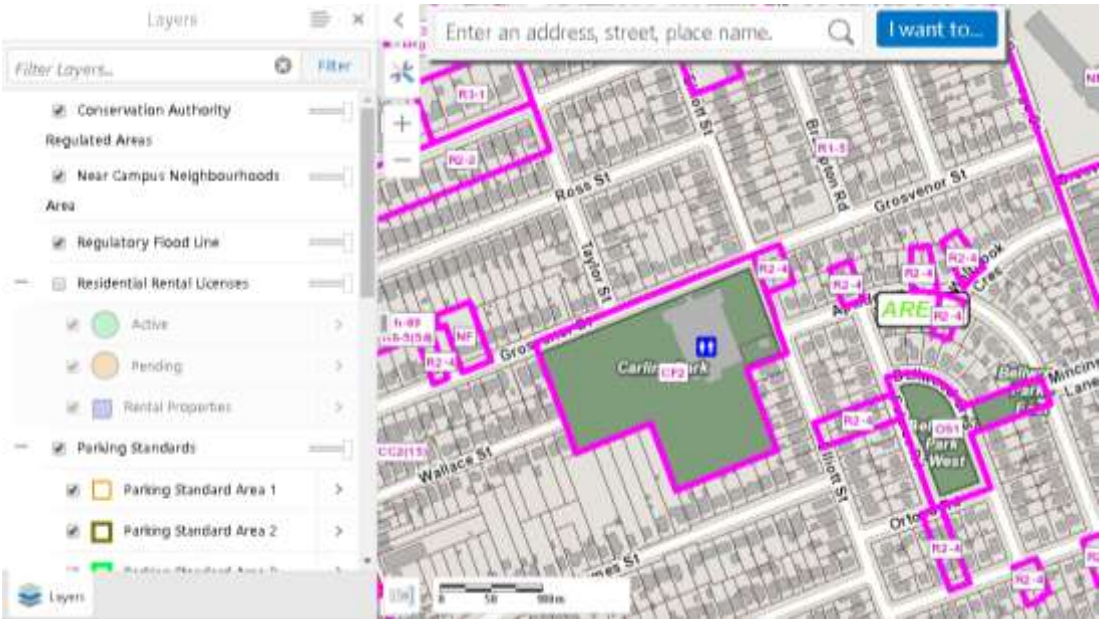


Figure 3.5: London, Canada: Showing the use of generalised zoning districts but no differentiation in symbology (City of London 2013b)

The coded names continue in the attribute dialog box. It is only once the user opens the regulations page that an understandable description becomes available. For the Residential R1 zone, there are more than 40 pages of regulations. This is in part due to the large number of variations in the zone: there are 179 variations within the zone. Initially this seems extreme but the variations address a question that arose in the course of this study: should zoning be applied by districts, or parcel-by-parcel?

Furthermore there are variations within the variant zones, differentiating between parcels along secondary collector and local streets.

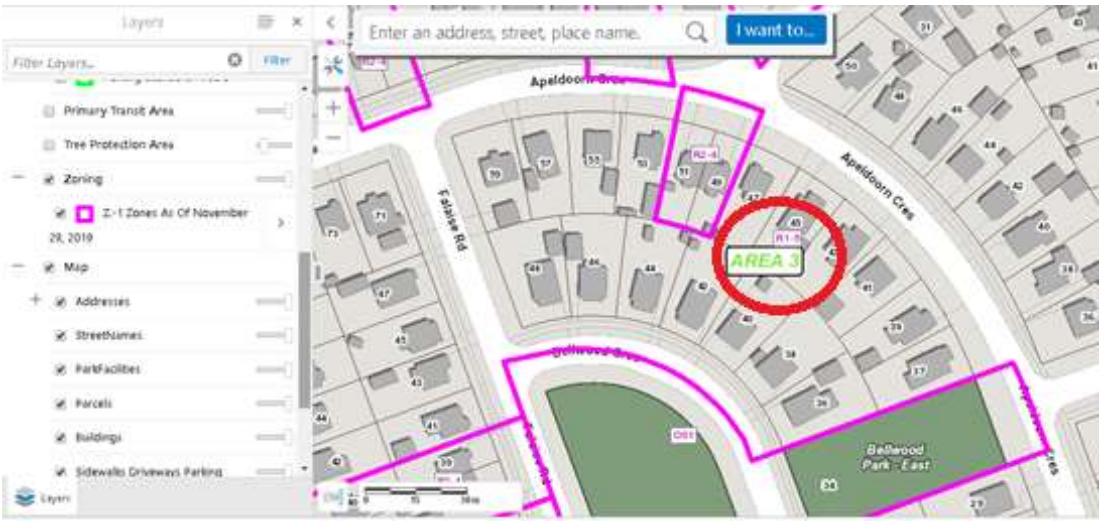


Figure 3.6: London, Canada: Showing coded zone description labels and parking overlay labels (City of London 2013b)

The regulations contain the typical regulations and some form-based controls. Among the typical regulations are floor area ratio (City of London 2013a: Chapter 5: 5.4.a), coverage (City of London 2013a: Chapter 5: 5.4.b), building height (City of London 2013a: Chapter 5: 5.4 b), setback lines (City of London 2013a: Chapter 5: 5.4.b), building lines (City of London 2013a: Chapter 5: 5.3), property size(City of London 2013a: Chapter 5: 5.3), parking requirements (City of London 2013a: Chapter 5: 4.a) and frontage (City of London 2013a: Chapter 5: 5.3.1). There are eight easily recognisable regulations.

Some of the variations include building form regulations such as the dimensions and positioning of garages. For example, variation R1-4(29) stipulates that the garage may "not project beyond the façade of the dwelling or façade (front face) of any porch, and shall not occupy more than 50% of lot frontage" (City of London 2013a: Chapter 5: 5.4.d).

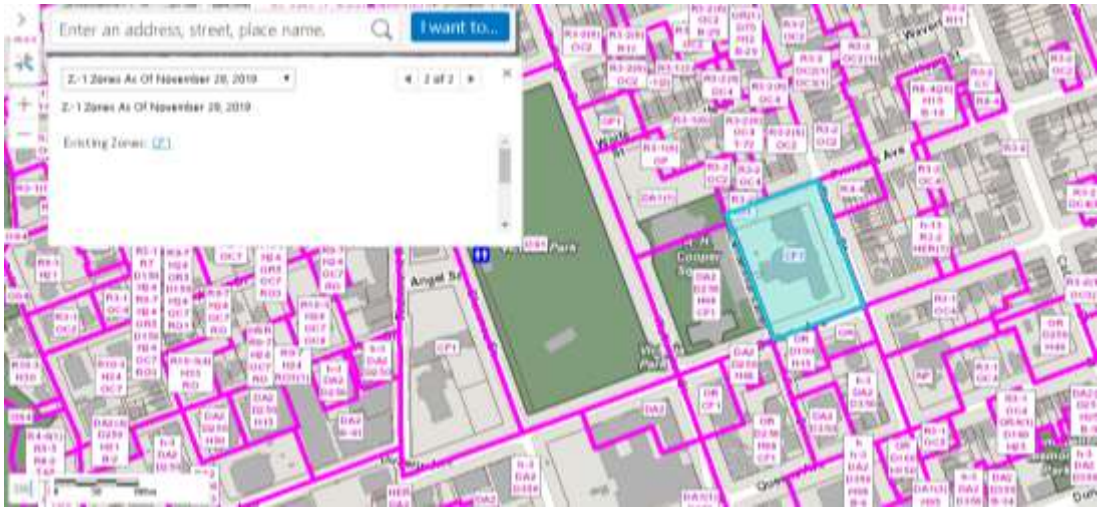


Figure 3.7: London, Canada: direct link to zoning regulations (City of London 2013b)

It is interesting to note that only one use is permissible in the zone. Within all 179 variations, only residential uses are allowed. The regulations, apart from the sheer number, read fairly simply and are fairly clear and straightforward.

3.4 City of Dublin, Ireland

The city of Dublin in Ireland uses a Euclidean style of zoning to manage land use and development. As opposed to the previous two cases, PDF maps were used depicting Dublin's zoning objectives. The style of zoning is Euclidean in nature although unique in this assessment.

Figure 3.8: Dublin: Showing Euclidean zoning and the use of unique symbols for categories (O'Hara, J 2016)

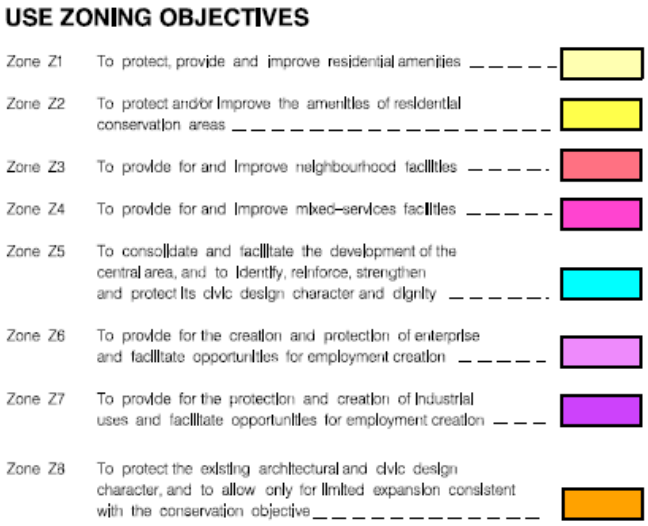


Figure 3.9: Dublin: Extract from the zoning legend (O'Hara, J 2016)

Dublin's zones are much more policy-like than typical Euclidean zones. "Zone 1: To protect and provide residential amenities", which is further investigated in this case study, sets the tone of the scheme. Industrial activities are housed in "Zone Z7: To provide for the protection and creation of industrial uses and facilitate opportunities for employment creation" (O'Hara 2016).

The map is cumbersome to navigate because of the amount of detail and size of the digital file as opposed to the other cases investigated. Zoning appears to be parcel-based but anomalies on the map suggest that it may also be district-based. There are fifteen distinct zones depicted. Apart from the zoning layer, there are twenty-four other layers of information shown on the map. These include several planning related layers such as a special development zone, the airport safety zone and strategic and redevelopment areas (O'Hara 2016).

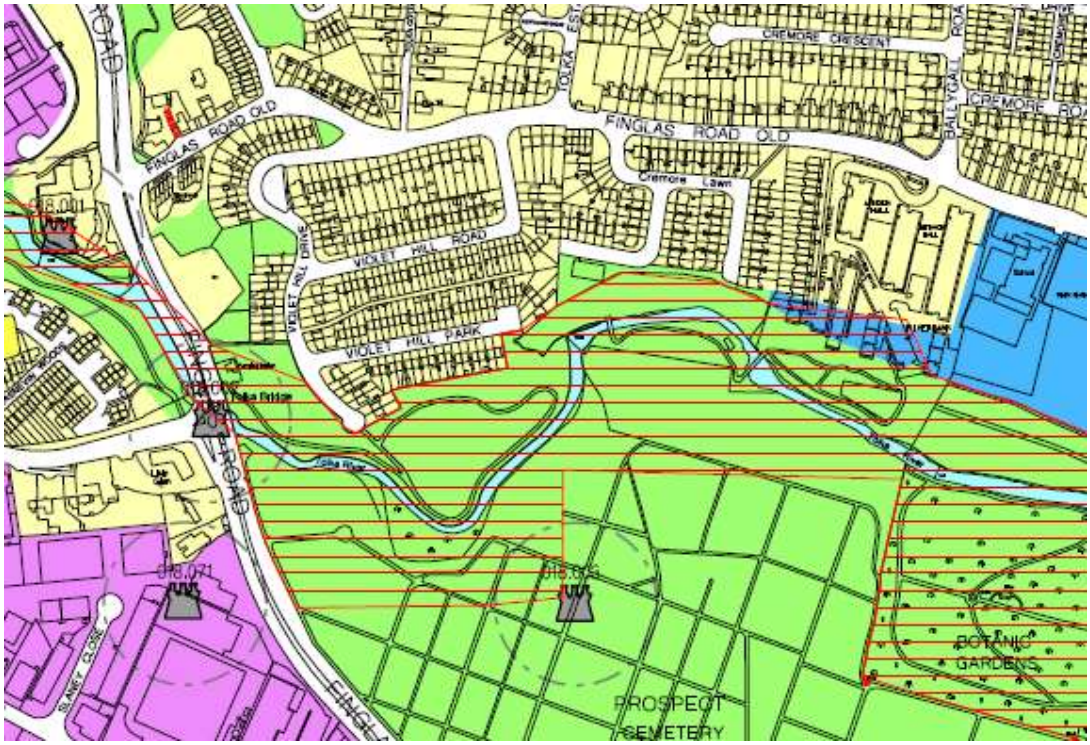


Figure 3.10: Dublin: Showing hatched conservation overlay zone (O'Hara 2016)

Since the map is a static image, there is no link to the accompanying written statement and it has to be located via a search engine or the Dublin City Council website. The written statement initially appears much more policy-orientated but still contains the usual controls and more (see Dublin City Council 2016).

The permissible uses are spelled out in a table and include two residential uses, twelve commercial uses, three utility and transport related uses and one open space use. Similarly, there are seventeen uses allowed with special consent (Dublin City Council 2016: 238).

The bulk and form controls are located in a later chapter but are referred to in the zone description section. There are many controls stipulated for the "Sustainable Residential Neighbourhoods-Zone 1" zone. They include floor area ratios (Dublin City Council 2016: 316), density (Dublin City Council 2016: 315), coverage (Dublin City Council 2016:317), height (Dublin City Council 2016:317-320), setback and building lines (Dublin City Council 2016: 336), landscaping (Dublin City Council 2016: 326-327), wall heights (Dublin City Council 2016:311), building form (Dublin

City Council 2016:325-328) and parking specifications (Dublin City Council 2016:336).

Apart from the typical controls, there are other detailed design controls such as apartment sizes, light requirements and even ceiling height. The written statement contains 408 pages of information.

None of the controls are shown on the map either graphically or textually.

3.5 Hong Kong, China

The city of Hong Kong has a web-map dedicated to zoning administered by the Hong Kong Town Planning Board. The city uses a variation of Euclidean zoning to manage its land use. Zones are shown by different colour symbols for different zones and legible descriptions with coded labels are shown in the legend. On the map, coded labels are shown on the various zones.

Figure 3.11: Hong Kong: Euclidean zoning and different notation for different zones (Hong Kong 2019)

There are twenty-eight different zones. These are not visible in the legend since the legend updates to show only those zones in the current map display. The full list of zones can be seen on the town planning board's master list of notes (Hong Kong 2018b), which has to be accessed manually through a search engine. There appear to

be very limited bulk controls in the scheme, with building height being the only stipulation. The height control is also shown on the map as point markers showing the maximum height in meters or floors.

Figure 3.12: Hong Kong: Showing additional controls (height) as marker and label on map (circles highlighting markers added by author) (Hong Kong 2019)

The Residential Group C zone has four permissible uses. Two of these are residential. There are twenty-six uses that may be allowed with special consent, of which fifteen are commercial in nature. The intention of the zones is stipulated as being low density residential but allowing for commercial activities that will serve the neighbourhood. The entire note is contained on a single page (Hong Kong 2018a).

The statutory note pertaining to the zoning of each parcel can be accessed by querying any parcel on the map (Hong Kong 2019), implying that the zoning is parcel-based. While only three layers are displayed in the legend, a wealth of additional geographic information is shown as the backdrop, including building footprints, parcel boundaries and embankments (Hong Kong 2019).

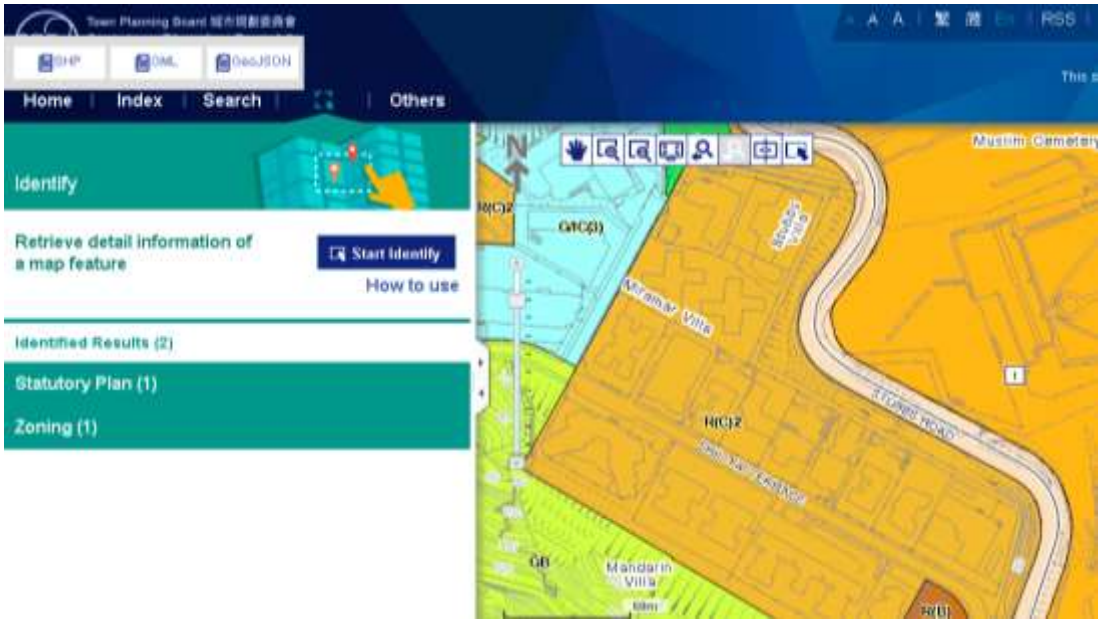


Figure 3.13: Hong Kong: Showing parcel-based zoning and link to regulations (Hong Kong 2019)

3.6 Christchurch, New Zealand

Upon initially viewing the zoning map of Christchurch in New Zealand, there appears to be a simple Euclidean zoning with a few zones. As with the Hong Kong map, the legend updates to show only the zones in the current view. With further interrogation, it is evident that there are twenty-eight zones on the map and fifty-four layers. Flood hazard, environmental asset, brownfield overlay area, noise zones and community housing development are some of the twenty-six layers that are directly planning related (Christchurch City Council, 2019a). The legend shows zoning descriptions and codes and the labels on the map reflect the zoning code.

Figure 3.14: Christchurch: Showing parcel-based zoning and varied notation for categories (Christchurch City Council, 2019a)

The regulations accompanying the map can be accessed directly from the map by clicking on any parcel. The zoning is parcel-based and only the zoning attribute is displayed (Christchurch City Council, 2019a).

Figure 3.15: Christchurch: Showing parcel attributes including coded zone for dissolved city blocks (circles added by author) (Christchurch City Council, 2019a)

As with the New York zoning website, Christchurch has a short note describing the zone as an intermediate to the full regulations. The description appears on the map and in much less detailed than the New York version.

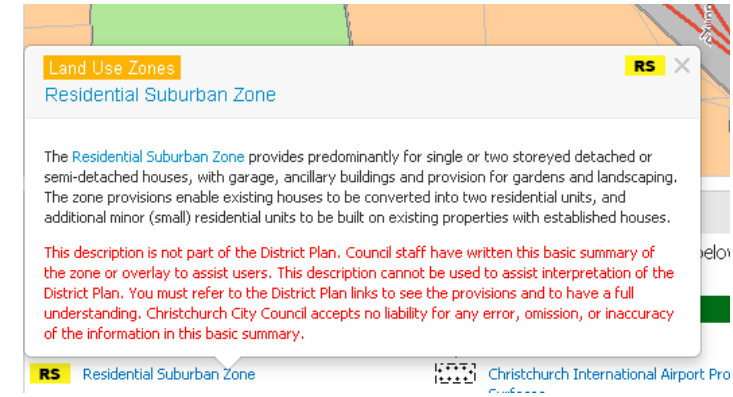


Figure 3.16: Christchurch: Showing narrative explaining zone characteristics to assist users (Christchurch City Council, 2019a)

The regulations reveal that the Christchurch scheme is anything but a simple Euclidean zoning ordinance. Rather it is a hybrid Euclidean, form-based, performance scheme. Use activities are defined (Christchurch City Council 2019b: para 14.4.1.1), form-based regulations are used (Christchurch City Council 2019b: para 14.4.3.2.12) and performance regulations are stipulated in places (Christchurch City Council 2019b: para 14.4.3.2.7) to control noise or operating times (Christchurch City Council 2019b: para 14.4.1.1.P20).

The Residential Suburban Zone and Residential Suburban Density Transition Zone contains forty-one pages of regulations. Explicit floor area ratio, density, frontage and parking specifications are not evident. Other typical zoning controls that form part of the scheme include: coverage (Christchurch City Council 2019b: para 4.2.4), building height (Christchurch City Council 2019b: para 4.2.2), setback lines (Christchurch City Council 2019b: para 14.4.2.9), building lines (Christchurch City Council 2019b: para 4.2.7), site size (Christchurch City Council 2019b: para 14.4.2.1), landscaping (Christchurch City Council 2019b: para 4.2.5) and wall heights (Christchurch City Council 2019b: para 4.2.10).

Other stipulations include daylight recession planes (Christchurch City Council 2019b: para 14.4.2.6), outdoor living space (Christchurch City Council 2019b: para 14.4.2.5) and tree and garden planting (Christchurch City Council 2019b: para 14.4.2.2).

Within the Residential Suburban Zone and Residential Suburban Density Transition Zone, sixty-nine variations were identified. Thirty-three permissible uses (Permitted uses and controlled activities) were identified, of which eighteen are residential in nature. Uses allowed by special consent (restricted discretionary activities, discretionary activities and non-complying activities) total forty of which twenty are residential in nature. None of the controls were shown on the map in graphic form or as attributes.

3.7 Cape Town, South Africa

Before going into detail about the city of Cape Town and its zoning system, it may be useful to consider zoning in the South African context.

There are obvious advantages to the use of GIS in zoning and land use regulation and many of these may be crucial for effective and efficient processes in a highly dynamic and increasingly competitive world. GIS could be applied anywhere in the world but because of its systematic nature (and the requirements that come with that) cognisance must be taken of the South African context and zoning.

As is the case in most colonised countries, the legal and planning systems, amongst other things, were adopted from the colonising power. South Africa inherited the British planning system and its use of ordinances in the pursuit of land use management. It is well documented that the spatial and legal legacy of the apartheid system has far-reaching and enduring implications. In terms of land use management, this is particularly evident in variant application of zoning (particularly as a tool to promote the "general welfare" of the population) in formal – and less formal – areas. Formal urban areas (mainly previously white settlements) are highly regulated and typically included within the extent of schemes (it should be added here that Yates (2006, cited in Nel 2015: 81-82) estimates that less than 15% of formal housing (likely white) in Pretoria complied with the town planning scheme AND national building regulations in 2006). Less formal (or informal) areas, typically black townships, may have schemes (or at least master plans), but twenty years post-apartheid, most still do not (and those that do, are not enforced). This differential approach is not only descendant of apartheid planning but common in many 'Global South' cities, and as Watson (2009: 176) argues, will be one of two results if typical land use regulations

are applied in cities with increasing poor populations. She suggests that those (the poor) not able to comply with regulations will move to where they can escape detection and so perpetuate sprawl (and the growth of areas developed in manners not promoting 'general welfare').

Parnell and Pieterse (2010) argue for land use management systems with specifications that include third generation rights which they define as citizen rights, "including the right to the city or a safe environment, to mobility or to public spaces" (Parnell and Pieterse 2010: 4). Furthermore the system should be a single system that is inclusive and transparent through defining norms, uses and tenure rights (Parnell and Pieterse 2010: 11,13). The application and enforcement of land use controls must be extended to all areas including poor and black areas where development occurs without consideration of health and safety despite current challenges (Parnell and Pieterse 2010: 16).

Nel (2016) explores an appropriate land use management system for South Africa by providing a list of criteria, which could be used to vet candidate systems. These include:

a) social sustainability including justice, equity and inclusion;
b) economic development through:
    i) creating and maintaining investor confidence, and
    ii) supporting property markets, jobs and livelihoods;
c) possessing financial and administrative viability including human resource capacity and administrative justice (transparency, participation and legitimacy); and
d) flexibility to accommodate changes but also a range of settlement patterns and forms of tenure (Nel 2016: 258-259).

The city of Cape Town in South Africa has a public web-map displaying forty-four layers of information. Zoning-related information is one of the key datasets in the collection, which is evident from its pertinence on the disclaimer dialog (see Figure 3.17 below). The city uses typical Euclidean zoning with overlay zones.

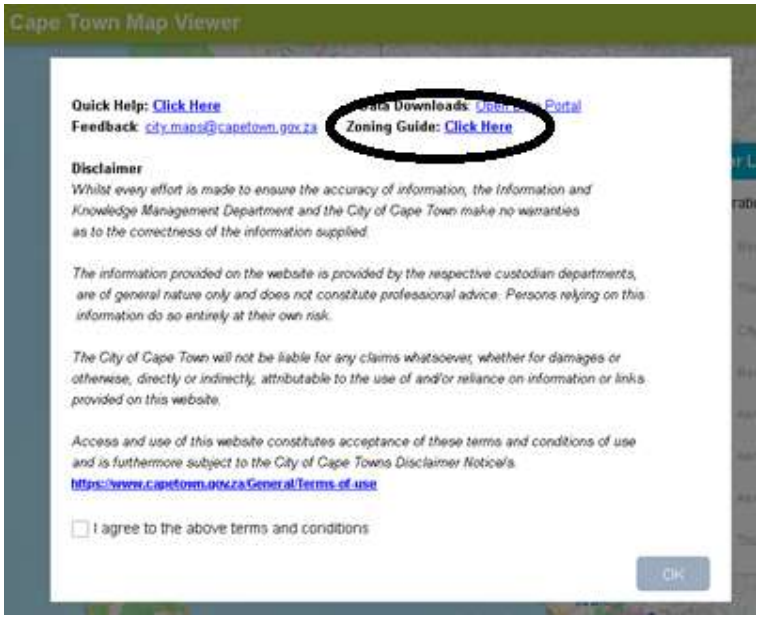


Figure 3.17: Cape Town: Showing link on disclaimer page (first page) to the zoning guide (circle added by author) (City of Cape Town 2019)

The map legend displays zoning descriptions and variable notations for the different zones. Coded zoning labels are drawn on each parcel of the map, implying that the zoning is parcel-based. The legend displays thirty-five different zoning categories (City of Cape Town 2019).

At least sixteen of the other layers are directly related to planning and include submitted BDM cases, submitted land use cases; split zoning sites, environmental resource management and urban development zones (City of Cape Town 2019).

Figure 3.18: Cape Town: Showing Euclidean, parcel-based zoning and variable notation (City of Cape Town 2019)

The zoning regulations cannot be accessed directly from the map. The controls were accessed manually from the municipal website (see City of Cape Town 2015). The "Single Residential zone 1: conventional housing" includes five of the typical bulk controls: floor area ratio, coverage, building height, setback and building lines (City of Cape Town 2015: 104-105).

Some conditions, such as keeping alterations compatible with the residential nature of the area, are added for additional use rights (City of Cape Town 2015: 104). The permissible floor area ratio is shown on the map for the central business district as polygon outlines of the district, but not for other areas (Figure 3.19).

Figure 3.19: Cape Town: Showing FAR control in selected areas graphically on map as district outlines (City of Cape Town 2019)

3.8 Summary

All of the case study areas used a form of Euclidean zoning, with Christchurch being the furthest removed from the standard. Hong Kong, while it separates uses, follows because of its scant bulk controls.

New York City and London, Canada use districts as the spatial vehicle for zoning, while the other four cities use land parcels. All six cities used some type of overlay zone. London was the only case where no zoning description was forthcoming on the map or legend, while Dublin was the only city not to use codes on the map. The other four cities used combinations of both codes and descriptions.

All cities were found to have height and setback controls. Only Hong Kong did not have explicit coverage and building line controls. Neither Hong Kong nor Cape Town set minimum lot sizes or parking requirements for the zones that were inspected. Wall height controls were not evident in half of the case study areas (Hong Kong, Cape Town and London), and neither were floor area ratios (Hong Kong, Dublin and Christchurch). Christchurch and Dublin were the only cities to set landscaping and building form controls.

Many other regulations exist that are very specific. In New York City, permissible obstructions in public spaces refer to regulations about air-conditioners or downpipes protruding into public space. London, Canada has regulations specifically pertaining to driveway dimensions of setbacks from road types. Very detailed regulations govern Dublin's apartment buildings, such as ceiling heights and minimum bedroom width. In Christchurch's residential zone, any vehicle and/or boat dismantled, repaired or stored on site must be the property of the people who live on-site. Finally, in Cape Town's residential zone, no more than six children shall be allowed to be enrolled in a home child care facility.

In four of the six cases, the regulations could be accessed directly from the web-map. Only Cape Town and Dublin's regulations needed to be located via the municipal websites.

Three of the cases had fewer than ten controls in the zone that was explored. New York City had ten, while Christchurch and Dublin had many more.
Half of the case study areas had at least one control graphically displayed on the map albeit as a label or non-distinct polygon. Cape Town was the only case where a legible polygon depicting a regulation was shown on the map, although the extent was limited to the central business district.

On average, there were around twelve permitted uses across the various case study areas. Residential uses numbered the most in the permissible categories, while activities that serve residents had the highest numbers in the category for special consent uses. The regulations for Dublin and Christchurch were difficult to navigate while those for Cape Town and Hong Kong were easy to read.

Chapter 4. Research methodology

4.1 Case study

The eThekwini municipality was chosen as the prime case study area. The municipality has a flexible, conventional zoning scheme with which the author is familiar. The municipality covers approximately 2292km^2 and is located on the east coast of South Africa. Three suburbs, Windermere, Springfield flats and Caneside, were chosen for in-depth investigation. The three suburbs comprised four thousand, four hundred and thirty-three (4433) parcels. The combined area of these suburbs totalled around 6.1km^2.

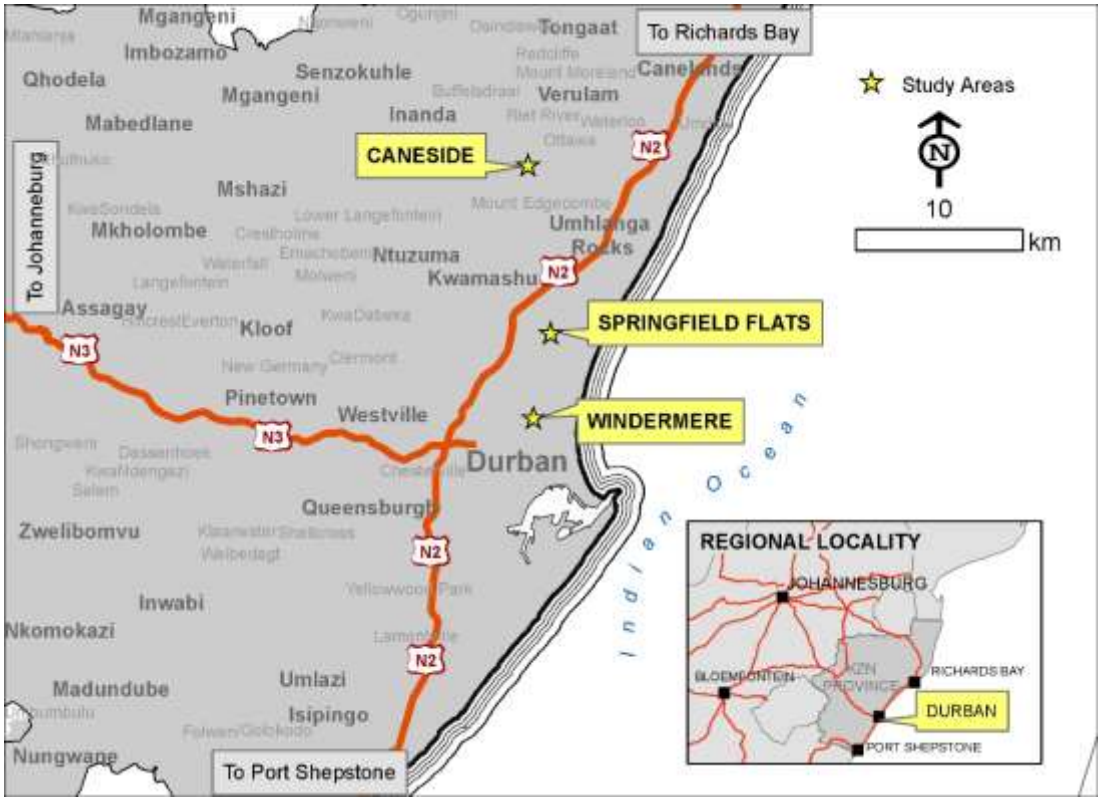


Figure 4.1: Location of sample study areas (author)

Daufuskie Island was chosen as a secondary study area since it is governed by a contemporary, form-based code, which was readily available on the Internet. The island is located on the east coast of the USA in the state of South Carolina. The island, a popular tourist destination, is approximately 32km^2 in size.

4.2 Research philosophy

The research methodology followed was a combination of quantitative and qualitative methods. This approach was used since determining what regulations were in existence, and to what extent those regulations can be represented in a GIS, is a secondary data, quantitative exercise. It was also thought prudent to collect some contextual information regarding municipal officials who manage zoning and GIS in a qualitative exercise.

4.2.1 Sampling

Purposive sampling was used in all facets of the study. The qualitative portion of the research provided contextual information and highlighted external factors that may influence the implementation of the model. This portion of the research focused on a small niche of planners that use both zoning and GIS in the eThekwini municipality.

The qualitative portion is based on the eThekwini municipality's zoning scheme and the Daufuskie Island form-based code. The Daufuskie Island code was chosen as a detailed, available and recent (adopted 2010) example.

Three test-case areas within the eThekwini municipality were chosen. These varied in character and land-use composition, which might not be gained through random geographic selection. As mentioned above, the suburbs included Windermere (mixed use), Caneside (residential) and Springfield Flats (industrial).

4.3 Data sources

4.3.1 Primary data sources

The aim of the primary data collected during this study was to provide insights into the municipal context. Confirming anecdotal knowledge regarding the software, capacity and other externalities within departments using both GIS and zoning, which influence the potential to implement a GIS-based zoning, would be key in formulating any proposal.

The qualitative data was obtained by means of questionnaires, which were submitted to the municipality's development controls department. This department is responsible for managing zoning data and information for the eThekwini metro and was chosen specifically because the personnel work with both GIS and zoning.

After gatekeeper approval was gained, relevant department heads were approached and requested to disseminate the questionnaires to willing participants. A letter of information and an informed consent form were attached to each questionnaire.
Weekly courtesy calls to department heads to check on the progress of the questionnaires were followed by the manual collection of all completed questionnaires, four weeks after delivery.

4.3.2 Secondary data sources

The aim of the secondary data was to identify which zones and regulations made which demands of a GIS.

The GIS data was obtained from the eThekwini municipality. In particular, suburbs, zoning parcels and other reference datasets were collected. The zoning parcels which fell inside the targeted suburbs were extracted for more detailed assessment. All three suburbs were located within the central zoning scheme of the eThekwini municipality and as such, the central scheme was collected for use. Using the GIS zoning parcel data, a summary of the zones within the three suburbs was created and those zones extracted from the scheme for the detailed analysis.

In total, four thousand, four hundred and thirty-three parcels (4433) were extracted, which contained thirty-six zones although only twenty-two zones had corresponding regulations. Two zones from the Daufuskie Island code were extracted for deeper interrogation.

4.4 Data analysis

For the quantitative analysis, a combination of GIS and Microsoft Excel was used to code, categorise and analyse results. Descriptive summaries and statistical analyses (such as the Frequency and Summary Statistics tools in the Analysis Toolbox in ArcMap and the Average, Mean, Mode and Percentage commands in Excel) reveal trends and outliers in order to aid the database model development and reveal focus areas for replicate studies.

The qualitative analysis used a combination of GIS and Microsoft Excel to code, categorise and analyse results. Again, descriptive summaries and statistical analyses reveal trends and outliers in order to aid the database model development and model implementation.

4.4.1 Content analysis

Content analysis is defined as a system "making replicable and valid inferences from data to their context" (Krippendorff 2018: 403). This is done through the systematic treatment of data to reveal patterns and trends that are not obvious (Krippendorff 2018: 404).

In performing content analysis we try to identify the variables that indicate the source (who), the coding process (why), the channel (how) and the consequences (on whom) (Krippendorff 2018: 403). In this case, by studying the online maps and zoning data of various cities, we identify the cities and some of their characteristics, the coding process and the reasons for communicating the information, the channel as in the method used for conveying the information (textual, graphical or otherwise), and the audience.

For Krippendorf, the data for content analysis is anything that occurs in significant numbers and "has a reasonably stable meaning for a specific group of people" (Krippendorff 2018: 404). In this case, a small sample is used to establish that some translation from textual regulations to mapped themes is taking place but that more could be done.

The most widespread use of content analysis is to infer the importance that the media or writers or cultures assign to a topic or person or subject (Krippendorff 2018: 404). In much the same way, it is used in this study to infer which regulations are considered more important by the publishing organisations, or to gauge the level of effort that is made by the organisation to make the information as digestible or understandable as possible (the comprehensibility). Content analysis may shed light on the kind of "values and expressed attitudes" to a specific topic (Krippendorff 2018: 405). In this case, it may provide hints as to value placed on transparent and comprehensible communication by the organisations.

The limitation of content analysis is mainly around the losses to qualitative values in the coding process. Also, if the variables have been identified directly from the sample, it may not be possible to replicate the study.

The research questions or inferences that are aimed at here include: what the most important regulations appear to be, which regulations are the most common, what the style of zoning is, what and how many additional reference layers there are, the level of detail that is available, how comprehensible the information is, how easily the information is accessed, and so forth.

4.4.2 Thematic analysis

Another method deployed involved thematic analysis where the researcher systematically identifies and organises data in order to reveal patterns of themes in the data. What makes thematic analysis different, is that the themes and specific questions develop during the assessment (Braun and Clarke 2012: 57).

The themes comprise sub-themes which in turn are clusters of coded values (Braun and Clarke 2012: 63). Good themes are distinctive and should be reported in sufficient detail to carry the richness and complexity of the data (Braun and Clarke 2012: 65).

4.5 Pretesting and modelling

Pretesting took place by developing a database model based on the results of the data analysis and applying the model to three case study areas within the municipality. The purpose of the exercise was to test whether the model was implementable and to record issues arising.

Arising from the data analysis, the regulations that could be added to a GIS database and in which form were identified. The data revealed that all the standard regulations in the scheme could be added as fields to the database. Some controls are naturally inclined to be represented spatially and could be used to generate map features.

The zoning data sample obtained from the eThekwini municipality was in shapefile format. To add some improved storage and performance functionality (ESRI 2020k),

it was decided rather to use the geodatabase format. Questionnaires completed by municipal staff confirmed that ESRI software is the software used by the organisation. Both shapefiles and geodatabases are native formats of ESRI products.

A new File Geodatabase was created and the zoning data was imported to create a polygon feature class. Data management tools were used to remove irrelevant fields in the existing database.

Based on the data analysis, a database schema was created to accommodate the required fields which would be added to the existing 'Zone Name' and 'Area' fields. Table 4.1 below shows the fields and their types.

Table 4.1: Fields added

Field Name	Alias	Type	Width
Hght	Height Reg	Text	20
EstHght	Est permissibale height (m)	Double	10
FAR	FAR Reg	Double	10
PAR	Permissible FA	Double	10
Cov	Coverage Reg	Double	10
CovM	Coverage (m)	Double	10
PLU	Permissible LU	Text	1000
SCLU	Special Consent LU	Text	1000
PrLU	Precluded LU	Text	250
BldgLn	Building line	Text	20
SideS	Side space	Text	20
RearS	Rear Space	Text	20
Minlot	Minimum lot size	Double	20
Access	Access Reg	Text	50
FlrArea	Floor Area Reg	Double	20
Dens	Density Reg	Text	50
DensEst	Estimated permissible density	Short integer	20

A table containing the zone name and the regulation values for each zone was created to allow for semi-automatic assignment of attributes to all the parcels in the database. The table was used in a table-join function to create a one-to-many relationship with the parcel's attribute table.

Table 4.2: Zoning regulations

Zone	Building L	BL values	Side space	SS values	Rear Spac	RS values	DU/Ha	DUHA val	Minimum	Size value	Height	H value	Coverage	Cov value	FAR	FAR value
Cemetery	1	7.5	1	3	1	4.5	0	N/A	0	Discretion	1	2	0	N/A	0	N/A
Creche	1	7.5	1	3	1	3	0	N/A	1	400	1	2	1	40%	0	N/A
Educational 1	1	7.5	1	3	1	3	0	N/A	1	2000	1	3	1	50%	0	N/A
Educational 2	1	7.5	1	3	1	3	0	N/A	1	2000	0	N/A	1	50%	1	2
Educational 3	0	N/A	0	N/A	1	Discretion	0	N/A	0	N/A	1	Refer	0	N/A	1	5.3
Existing Street	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Extended Residential 650	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
General Business 2	0	N/A	0	N/A	0	N/A	0	N/A	1	900	1	25	0	N/A	1	2
General Industrial	1	0	1	0	1	0	0	N/A	1	900	1	25	0	N/A	0	N/A
General Residential 1	1	7.5	1	3	1	3	1	is Floor ar	1	900	1	ess shown	1	50%	1	1.2
General Residential 2	1	7.5	1	3	1	3	1	is Floor ar	1	900	1	ess shown	1	50%	1	1.2
General Shopping	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Government and Municipal	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Indeterminate	1	7.5	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A
Institutional 2	1	7.5	1	4.5	1	4.5	0	N/A	1	Discretion	0	N/A	1	50%	1	1.5
Institutional 4	1	7.5	1	3	1	3	0	N/A	0	N/A	1	2	0	N/A	0	N/A
Light Industrial	1	ite specifi	0	N/A	0	N/A	0	N/A	1	900	1	25	0	N/A	0	N/A
Maisonette 650	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Maisonette 900	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Minor Shopping	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Mixed Use	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
New Street	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Office	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Petrol Service Station	1	7.5	1	3	1	3	0	N/A	1	900	1	2	1	50%	0	N/A
Place of Worship	1	7.5	1	3	1	3	0	N/A	1	1800	0	N/A	1	50%	0	N/A
Public Open Space	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Special Residential 180	1	2	1	1	1	1	1	1/180	1	180	1	2	1	75%	0	N/A
Special Residential 400	1	3	1	1	1	1	1	1/400	1	400	1	2	1	50%	0	N/A
Special Residential 650	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Special Residential 900	1	5	1	2	1	2	1	1/900	1	900	1	2	1	50%	0	N/A
Special Shopping	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Special Zone: Umgeni busine	1	0	0	0	0	0	0	0	1	900	1	15meters	1	pecific site	1	pecific site
Special Zone: Greyville villag	0	N/A	0	N/A	0	N/A	1	1/200	1	400	1	2	1	50%	1	0.8
Special Zone: Atherton	1	per diagra	1	rey which	1	rey which	0	N/A	0	N/A	1	roof ridge	1	40%	0	r area: 17
Special Zone: Springfield Roa	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99
Transport Zone	1	7.5	1	3	1	3	0	N/A	0	N/A	1	igher than	1	igher than	1	igher than

Following the table join, each field in the zoning feature class was edited to reflect the applicable regulations. With the parcels in the database having regulations, the digitizing of building lines, side space and rear space regulations could commence. The process of offsetting lines in ArcMap was found to be too time-consuming without adding additional value, and the process was moved to the AutoCAD environment. The cadastre was exported to CAD. Since the building line, side space and rear spec attributes were already in the layer, labels could be created showing the regulations on each property. These labels were also exported to CAD to inform the offset process.

Once the line data was created, it was imported into the geodatabase as a new feature class. To ensure that the data was topologically correct, the line data was overlaid on the cadastre using the Intersect function. Apart from calculating where the lines cross property boundaries and splitting them at that point, ‘Intersect’ also assigns the attributes of the property wherein a line falls, to the line – in this case, the property description and regulations. To enhance data quality, the Dissolve function was used along with the property description to reduce line segment records in the dataset. The symbology, labels and visible scale range for the lines were set.

The symbology for the zoning layer was set to display the zoning descriptions as unique values. The same layer was copied and symbology settings to reflect the floor area ratio (FAR) and coverage values were set.

4.6 Validity and reliability

In terms of the qualitative research, the reliability of the research is ensured through the design of structured assessment forms and guidelines to direct decisions. The validity of the research was ensured by relying on the theories of GIS and planning to inform the structure of the assessment.

As for the quantitative research, the reliability of the research was ensured through the design of structured questionnaire with unambiguous, clear questions. As above, the validity of the research was ensured by relying on the theories of GIS and planning to inform the questionnaire. Furthermore, the purposive sampling method limited respondents to persons familiar with either the zoning tools, GIS or both.

4.6.1 Limitations

Some limitation in available time limited the extent of the case study areas but this should have little effect since the purposive sampling approach allowed for the selection of areas providing a range of zones and regulations. Non-responsiveness of respondents to the questionnaire implied less contextual information, which was regrettable, but of little consequence to the outcome of the study.

4.7 Conclusion

This chapter highlighted the approach and methodology employed in this study to answer the research questions. Purposive sampling was used in both quantitative and qualitative approaches to ensure valid and appropriate responses. The quantitative portion of the research focused on identifying which demands were made by the zoning schemes of a GIS while the qualitative research provided insights into the contexts within the municipal organisation.

Chapter 5. Data analysis, findings and discussion

5.1 Introduction

Data for the study was collected using both quantitative and qualitative techniques. The quantitative data focused on the scheme and zoning data while the qualitative data provided context and insight in the use of GIS and zoning data at the eThekwini municipality. The key assessment is the quantitative analysis, which speaks directly to the research questions regarding the demands that the scheme makes of a GIS and whether, and how, those demands can or cannot be met.

5.2 The quantitative data assessment and results

The quantitative data collected for this study came from three sources: the eThekwini GIS Zoning dataset, the eThekwini scheme document and the Daufuskie Island Code. Three suburbs in eThekwini were chosen to ensure that a variety of zones could be sampled. Similarly, two of the seven zoning districts from the Daufuskie code were chosen.

The samples were interrogated with the aim of identifying which regulations occur in conventional and alternative zoning schemes and how these could be represented in a GIS. The zoning data for eThekwini was extracted for relevant suburbs and a summary description of this data showed thirty-six zones. It was later found that only twenty-two zones had corresponding regulations in the scheme. Thus, twenty-two zones for eThekwini and two zones for Daufuskie Island were interrogated.

Further to collecting information on what the regulations entailed, consideration was also given to additional text regulations, spatial variance within regulations (where different controls apply to particular land parcels within the zone), the type of value of the regulation, the options for including the regulation in a database or on a map and so forth.

Table 5.1: Zones interrogated

Zone	No. of Parcels
Cemetery	1
Creche	4
Educational 1	31
Educational 2	7
Educational 3	3
General Business 2	182
General Industrial	255
General Residential 1	244
General Residential 2	716
Indeterminate	12
Institutional 2	16
Institutional 4	1
Light Industrial	62
Petrol Service Station	22
Place of Worship	21
Special Residential 180	1867
Special Residential 400	7
Special Residential 900	44
Special Zone: Umgeni business park	88
Special Zone: Greyville village	85
Special Zone: Atherton	1
Transport Zone	47
Suburban Transect Zone (D3)	District
General Urban Zone (D4)	District

5.2.1 eThekwini Cemetery zone

Only one parcel in the study area is zoned for cemetery use. The zone has four regulations. These include building lines, side space, rear space and height. All are considered to be nominal or descriptive except for the height regulation which may also considered as a ratio value.

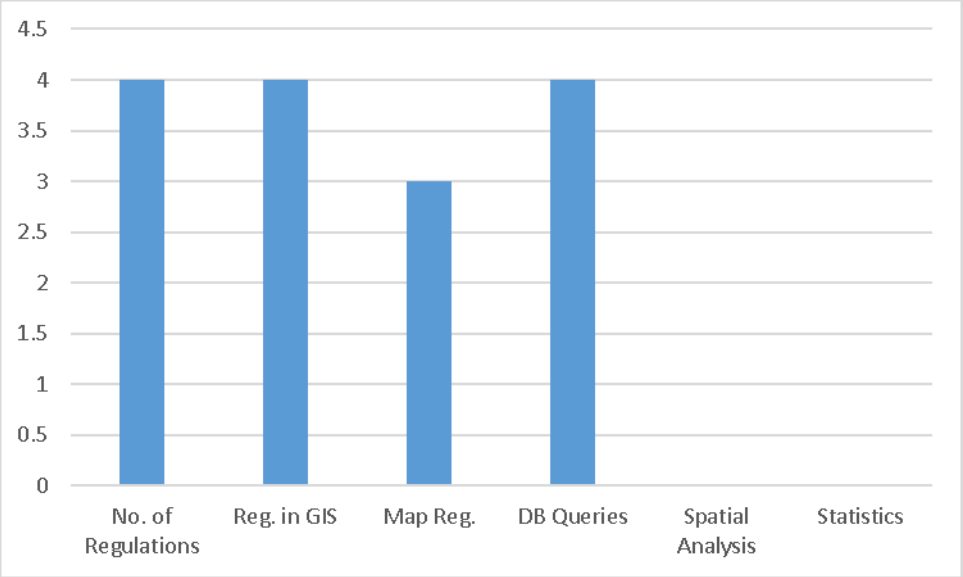


Figure 5.1: Cemetery zone regulations

There are four permitted land uses in the zone and five uses that require special consent. All other uses are precluded. The additional controls deal with landscaping and use conditions. While all of the regulations can be incorporated in a database, only three can be shown as a feature on a map that is not a label. There was no variation in any of the controls.

5.2.2 The eThekwini Crèche zone

There are two permitted land uses and five activities that need special consent in the zone. The precluded use category is open-ended and prohibits all activities not specified in the permitted or special-consent categories. The sample contained just four parcels zoned for crèche use.

The standard regulations for the zone include building lines, side and rear space, height, minimum lot size and coverage. There are six regulations. Half of the regulations are ratio values and the other half are descriptive. Additional controls deal with use conditions and parking requirements.

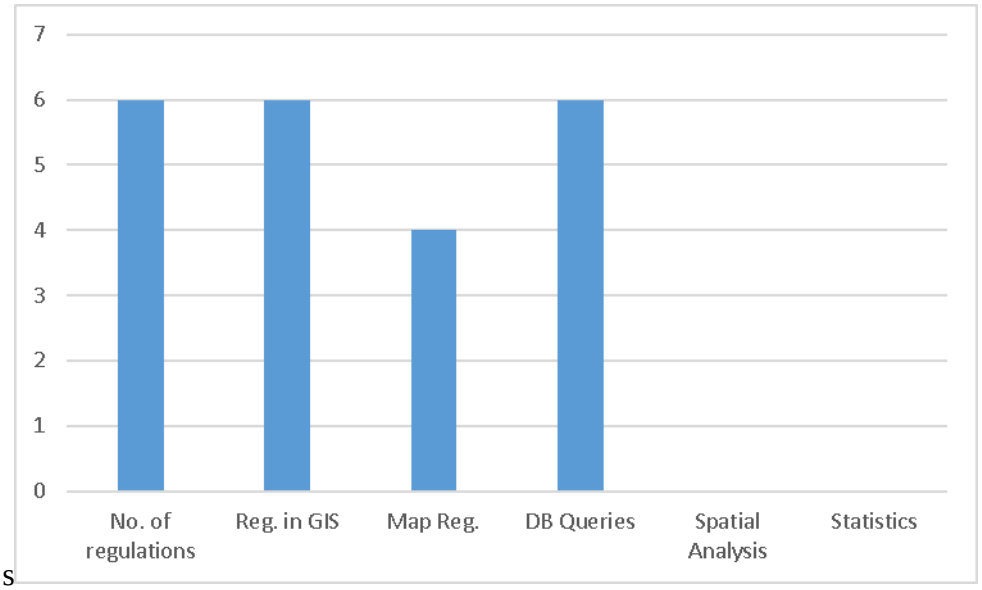


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Figure 5.2: Crèche zone regulations

All the regulations can be added to a GIS database to be queried spatially or using standard query language (SQL), but only four of the regulations can be shown on a map as a geographic feature. All regulations can be shown on the map as labels.
No variation within the zone was evident.

5.2.3 eThekwini Educational 1 zone

There are thirty-one properties in the sample that are zoned as Educational 1. The zone specifies ten uses as permissible and six other uses that require special consent.

Half of the regulations are descriptive and use nominal values whereas the other half use ratio values. The six different regulations are comprised of coverage, minimum plot size, height, building lines and side and rear space.

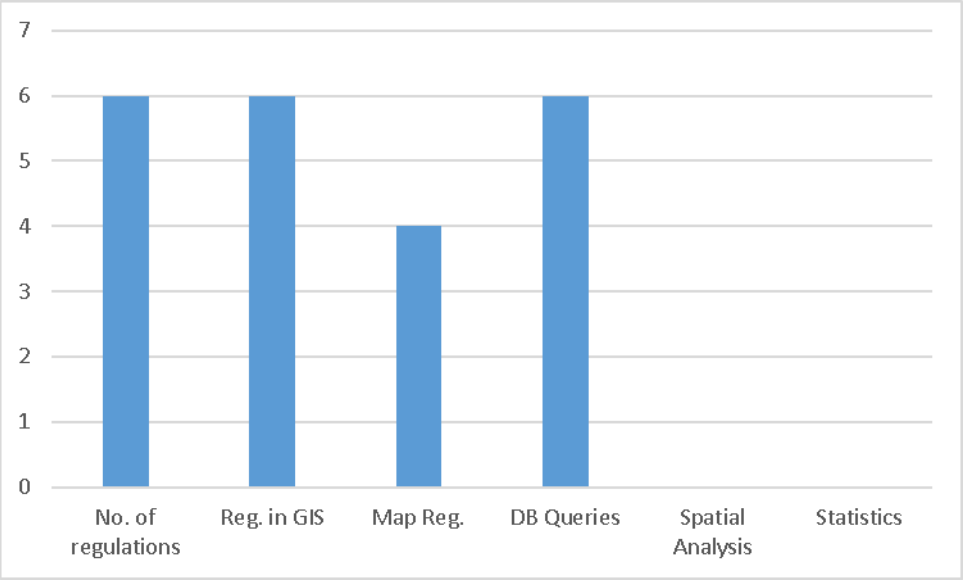

Figure 5.3: Educational 1 zone regulations

The additional regulations are descriptive and deal with conditions of use such as accommodation for caretakers and students or allowing worship activities. No variation within the zone regulations are specified. All the controls could be added to a database but only four could be used to features on a map other than a label.

5.2.4 eThekwini Educational 2 zone

Of the six standard controls in the Educational 2 zone, five could be mapped as geographic features and two may have useful statistical values in a GIS.

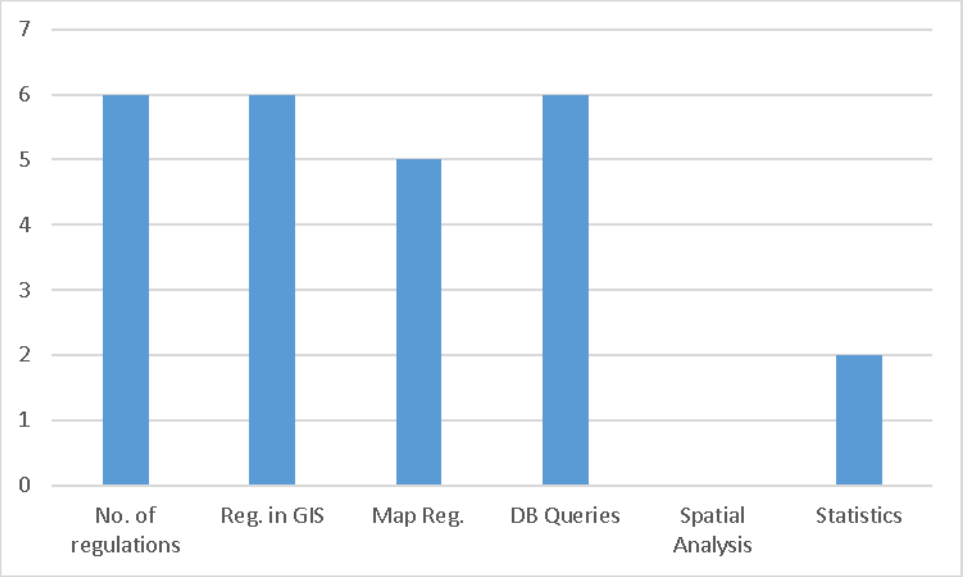

Figure 5.4: Educational 2 zone regulations

There are no variations within the zone's controls. Floor area ratio, coverage, minimum plot size, building line, side space and rear space are the controls applied to the zone. This implies that half of the controls are descriptive and the other half use ratio values. The permitted land uses in the zone include educational establishments, ancillary shops and accommodation. There are nine permissible uses and a further seven that are allowed with consent from the municipality. The additional controls relate to conditions for ancillary activities. Only seven land parcels in the study area are zoned Educational 2.

5.2.5 eThekwini Educational 3 zone

The zone is designed for education activities in high density areas and there are only three standard regulations. They are rear space, floor area ratio and height, respectively they are nominal, ratio and ratio type values. The additional controls relate to the ancillary uses among the nine permissible and seven special consent uses. The 'precluded use' category remains open ended.

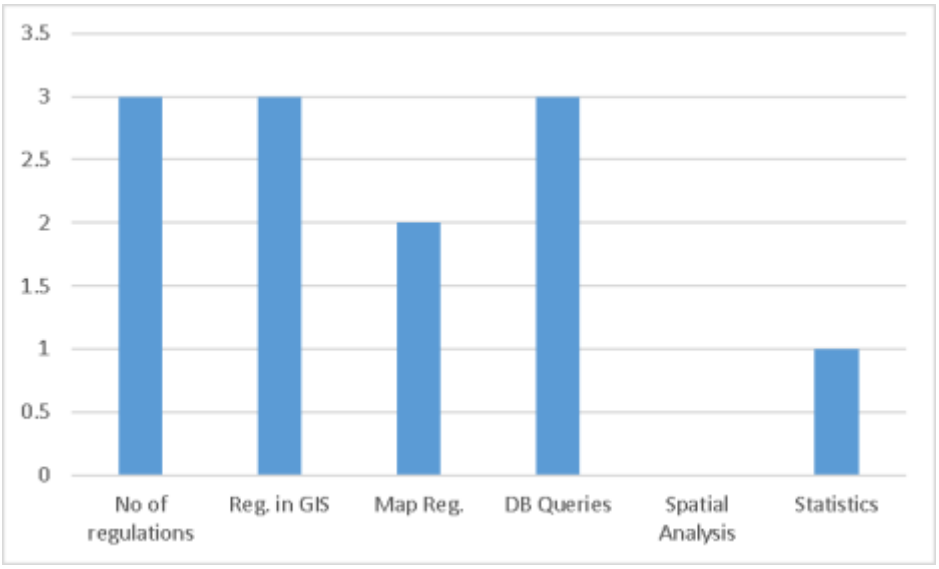

Figure 5.5: Education 3 zone regulations

The zoning controls of the three land parcels that are zoned Educational 3, can all be added to a GIS database. Only two are considered viable for mapping.

5.2.6 eThekwini Fuelling Station zone

The fuelling station zone has six uses that are permissible and another six for which special consent must be obtained. The additional controls relate to landscaping, dwelling use conditions and shop floor areas. A variation in the control is access. A specific site, on Old Mill Way, may not be accessed from Holmark Place. The standard regulations include building lines, side space, rear space, height and coverage. This implies four descriptive controls and three ratio value controls.

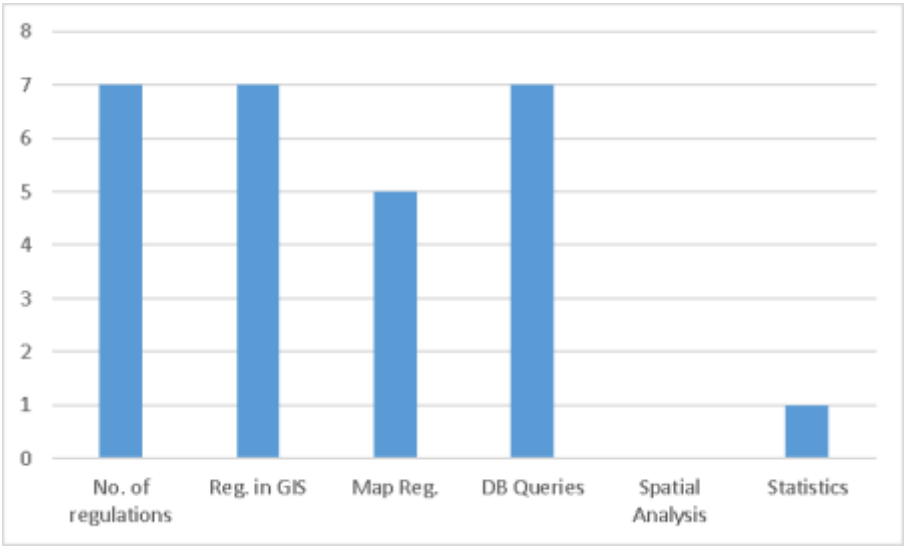

Figure 5.6: Fuelling station zone regulations

In the sample dataset, there are twenty-two properties zoned as Fuelling stations. All of the controls can be added into a GIS database of which five could be either spatial or attribute or both.

5.2.7 eThekwini General Business 2 zone

The General Business 2 zone articulates thirty-eight uses as permissible and thirteen others allowed with special consent. In the sample, one hundred and eighty-two parcels fall in this zone.

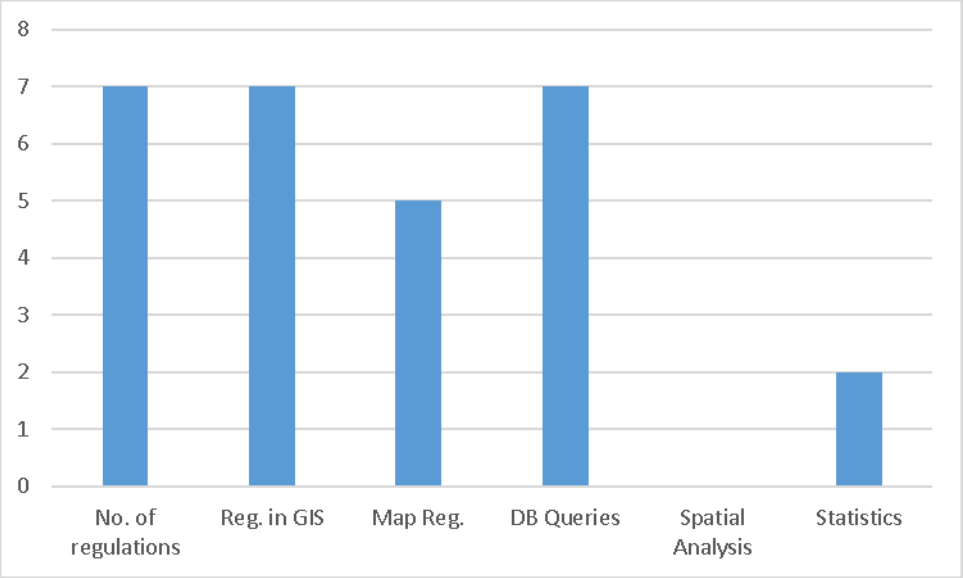

Figure 5.7: General Business 2 zone regulations

There are seven standard regulations in the zone which include height, minimum lot size, floor area ratio, coverage, building line, access and side space. The coverage, access and building lines are specified in the additional control and only applies to some parcels. The specification of building line and coverage regulations in the additional controls implies that there is variation within the controls since none of the other sites have these regulations.

Ratio values are for seven of the regulations, with nominal descriptive values for the remaining two. Only two of the regulations must be included as non-spatial attributes; the other five can be shown on the map and stored as an attribute.

5.2.8 eThekwini General Industry zone

The General Industry zone has only two regulations: height and minimum site size, which both use ratio values are both more suited to be stored as attributes. The sample contains two hundred and fifty-five properties zoned as General Industry.

The additional controls create variation by allowing student accommodation on 56 Calais Road in Congella.

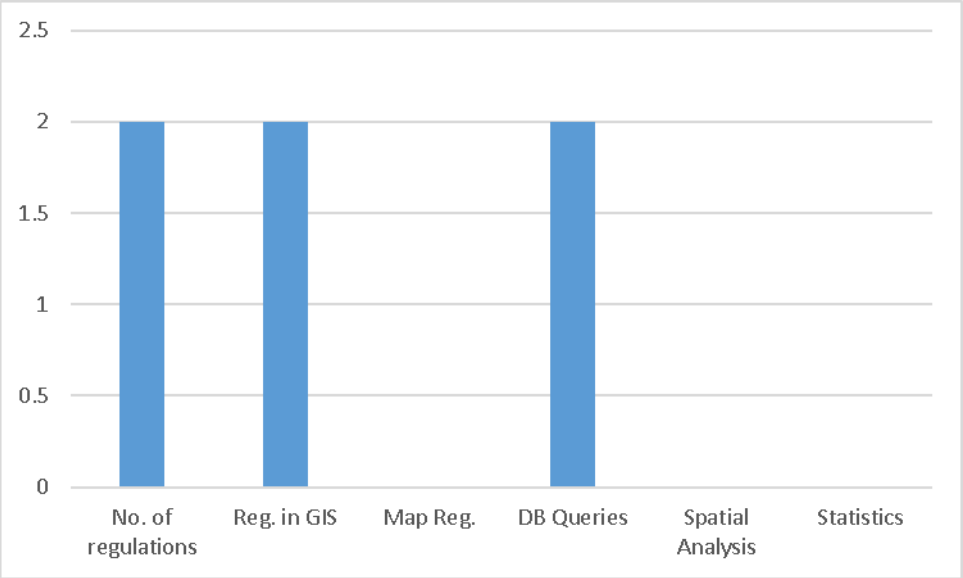

Figure 5.8: General Industry zone regulations

Permissible land uses in this zone include general and light industry, workshops and scrap yards amongst the twenty-three open uses. An additional twenty-three uses are permitted with special consent.

5.2.9 eThekwini General Residential 1 zone

This zone caters for accommodation uses of higher density as well as the ancillary uses that serve communities. There are six permissible land uses, all residential, and another fourteen uses which require special consent.

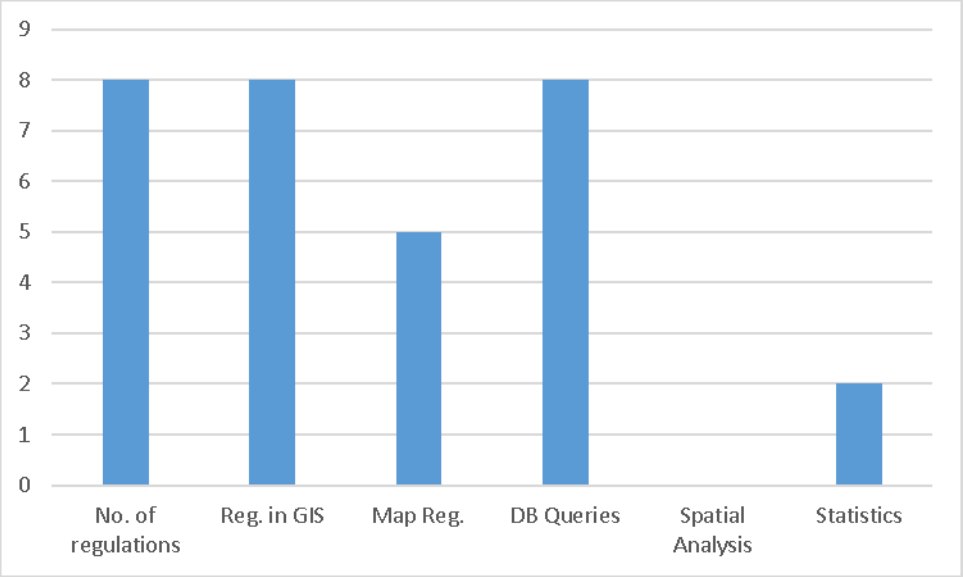

Figure 5.9: General Residential 1 zone regulations

In the study area, two hundred and forty-four parcels fall in this zone. There are eight regulations in the zone. These include building lines, side space, rear space, height, minimum lot size, coverage, floor area ratio and density. The additional controls have variations in the height and coverage controls which affect thirty parcels.

Half of the regulations use nominal values and the other half use ratio values. All of the regulations can be stored in a GIS database but two are mainly suited to be attributes.

5.2.10 eThekwini General Residential 2 zone

The General Residential 2 zone is very similar to the General Residential 1 zone. The only difference is that the density allowed in this zone is lower. The permissible land uses and special consent uses, respectively, also number six and fourteen.

The regulations are the same as the General Residential 1 zone with building lines, side space, rear space, height, minimum lot size, coverage, floor area ratio and density, with the density value being the only difference.

The additional controls relate to landscaping, bulk, use conditions and other regulations. Variations to the standard controls in the height and density categories affect four parcels. There are seven hundred and sixteen parcels in this zone.

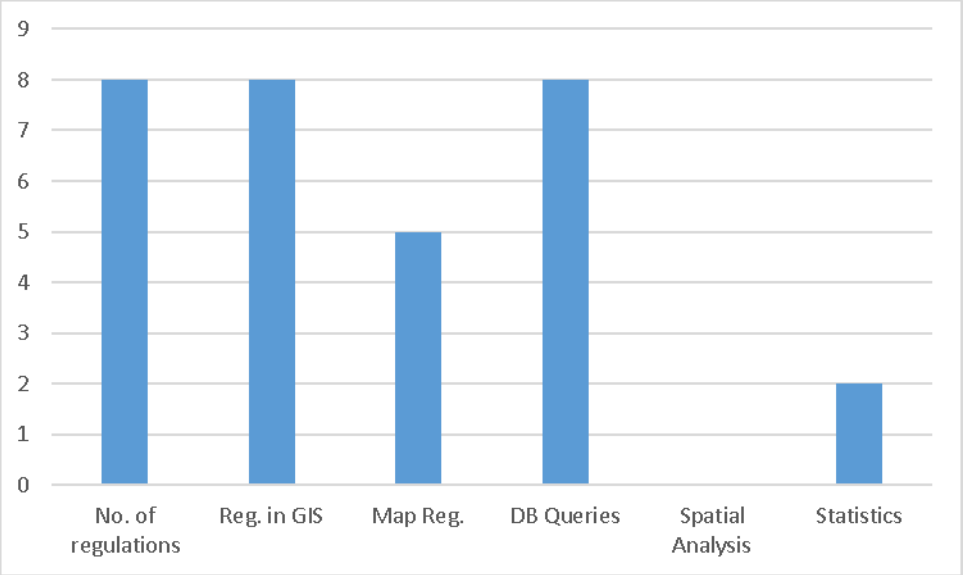

Figure 5.10: General Residential 2 zone regulations

All of the regulations can be added to a database; however five can be shown on a map as geographic features. At least two of the regulations can yield useful statistics.

5.2.11 eThekwini Indeterminate zone

No permissible or precluded uses are specified for the Indeterminate zone. All uses are by special consent but not stipulated in the standard format. The additional controls specify six permissible uses for one lease.

The dataset contains eleven parcels zoned Indeterminate but the additional controls reveal another spatial aspect in the form of leases. Leases do not form part of the cadastral fabric but are stored in a separate layer. This has implications for representing zoning and spatial analysis.

The only standard regulation in the zone is a 7,5m building line, with the additional control being a body of text. This implies that mainly nominal values are required. The building line can be added to the map.

5.2.12 eThekwini Institutional 2 zone

This zones serves the need for institutions such as hospitals, nursing homes and mortuaries. The permissible land uses total eleven and the uses that need special consent total thirteen.

The seven regulations pertaining to this zone include building lines, side and rear space, height, minimum lot size, coverage and floor area ratio. The height control is at the discretion of the municipality rather than an absolute value. Variation within the building line, height, floor area ratio and coverage regulations is created in the additional controls. These four variations affect four properties, meaning that there are sixteen variations.

Three of the regulations use nominal values while the other four are ratio values.

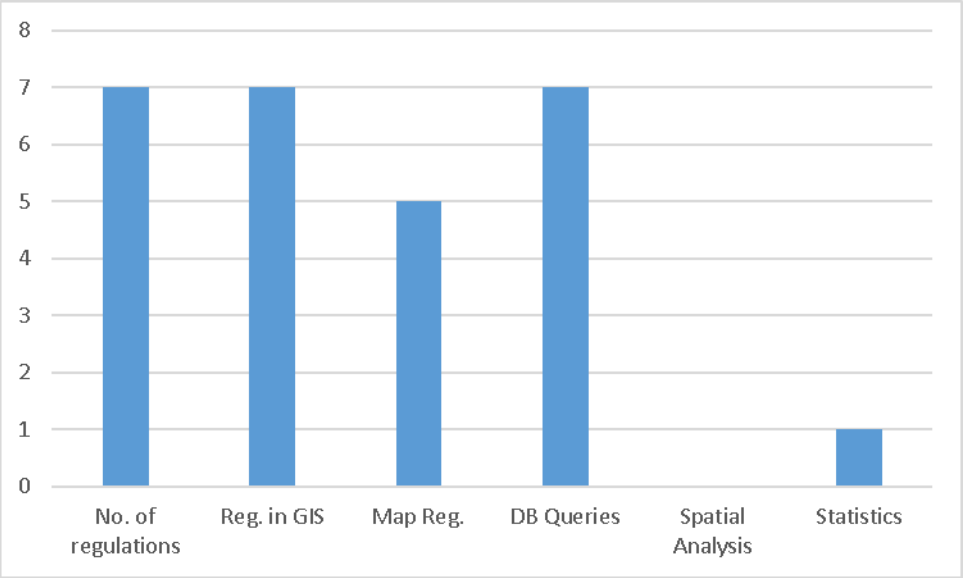

Figure 5.11: Institutional 2 zone regulations

All of the regulations can be added to a GIS database but only five can be both displayed on the map and kept as an attribute. There are sixteen land parcels in the zone in the sample.

5.2.13 eThekwini Institutional 4 zone

There are three descriptive and one ratio value regulations in this zone, which includes building line, rear space, side space and height.

The zone serves the needs for animal-related activities such as veterinary clinics and riding stables. There are twenty uses permitted and an additional six uses with special consent.

Only one property in the sample dataset is zoned Institutional 4. The additional controls are related to landscaping, use conditions and site layout without creating any variation within the controls. Of the four controls, three can be displayed on a map and one is better suited to be stored as an attribute in the GIS database.

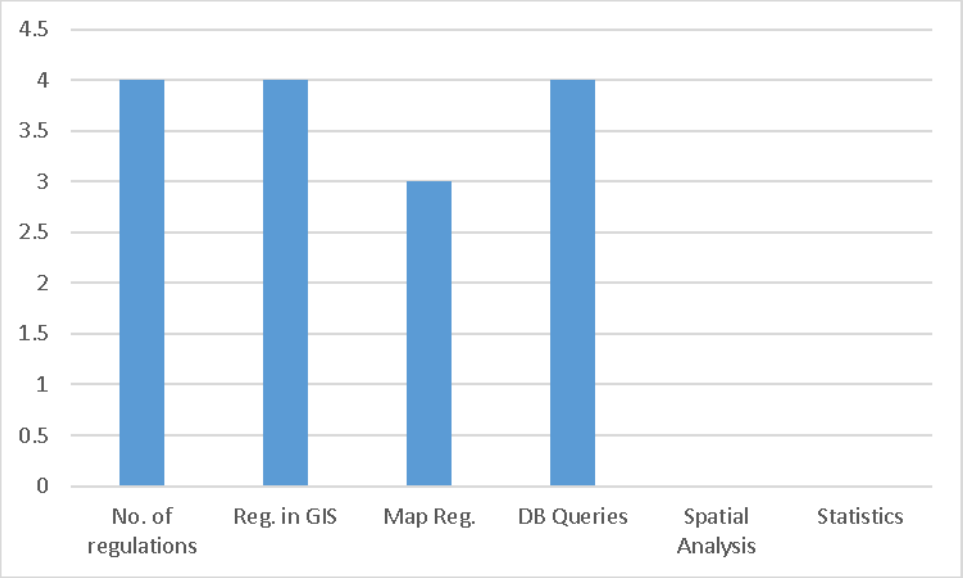

Figure 5.12: Institutional 4 zone regulations use

5.2.14 eThekwini Light Industry zone

The Light Industry zone specifies forty-eight uses of which seventeen are open and the other thirty-one require special consent.

Permitted land uses include warehousing, container depot and motor workshops. Uses such as crematoria, nightclubs and general industry require special consent.

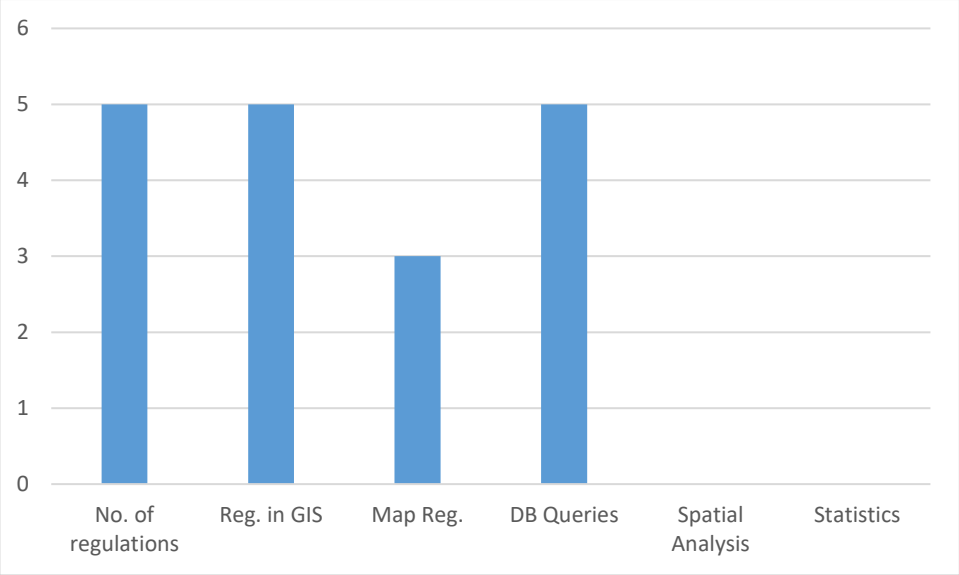

Figure 5.13: Light industry zone regulation use

In the sample dataset, there are sixty-two properties that are zoned for light industrial use.

Although the additional controls create variation in the zone, the standard regulations include coverage, minimum lot size, rear space, side space and building lines. The variations occur on four properties. All the regulations can be stored and queried in the GIS database. Only the building lines and side and rear spaces can be shown on the map.

5.2.15 eThekwini Special Zone Atherton

There are six regulations for the single parcel zoned Special Zone Atherton. Notwithstanding the site being declared a monument, building lines, side space, rear space, height, coverage and floor area regulations are applicable. Apart from coverage, the regulations are not communicated in the standard form. The building line control refers to the diagram shown in the additional control space. The height is specified as "Not to exceed the roof ridge line of the "House" (eThekwini Municipality 2019b: 131). The side space is specified as either 3m or 1,2m per storey, whichever is greater. Rear space is 5m or 1,2m per storey, whichever is greater. Furthermore, floor area is exactly specified to be 1776m^2. Half of the regulations are nominal in nature and the other half are ratio values. There are four uses permitted on the site, with no special

consent uses. All of the regulations can be accommodated in the GIS database. Manual calculations to convert descriptions to values are required to standardise the controls.

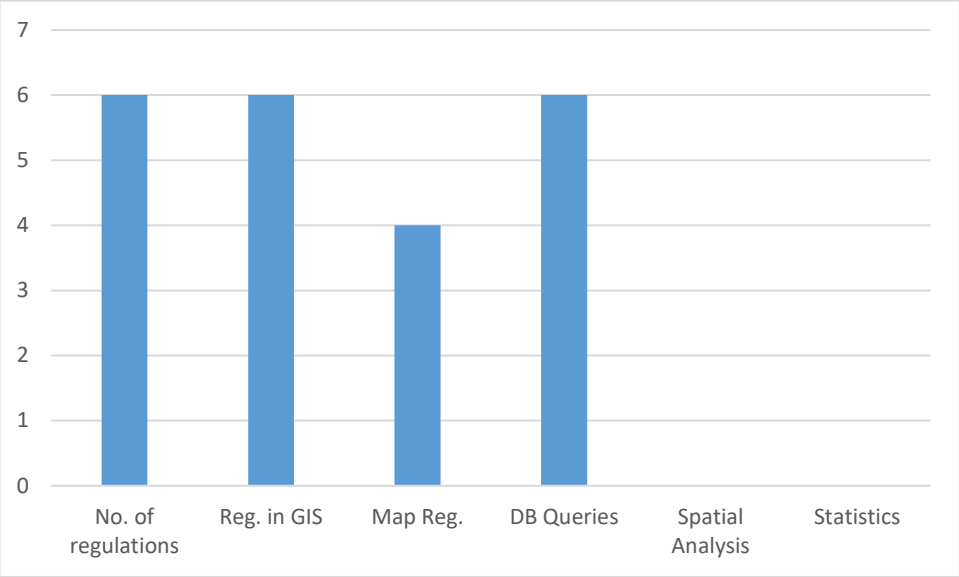

Figure 5.14: Atherton zone regulation use

5.2.16 eThekwini Special Zone Greyville Village

This zone is predominantly residential with a quaint character. It is located on eighty-five land parcels. As it stands, only two uses are permissible but the additional controls stipulate that business activities may also be permitted with special consent.

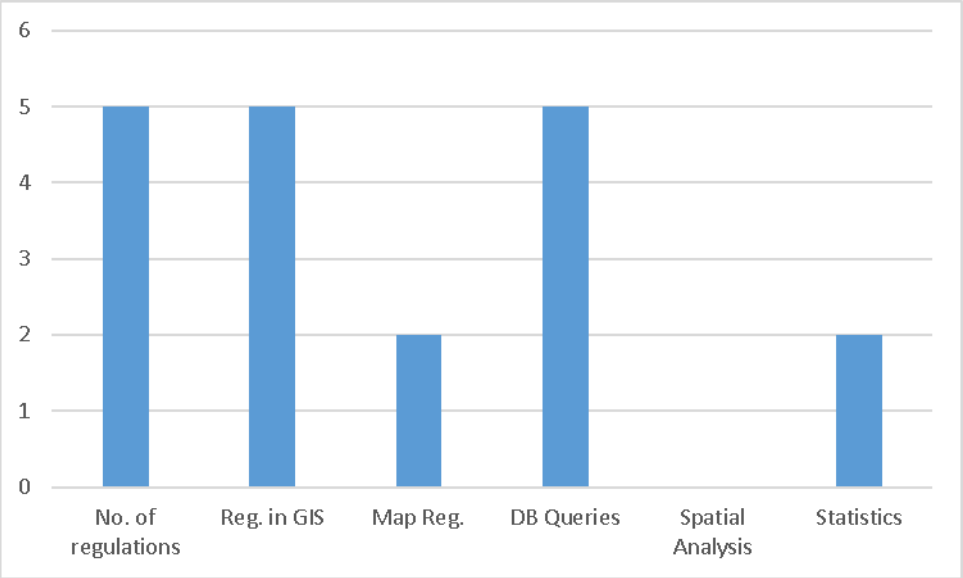

Figure 5.15: Greyville Village zone regulation use

Height, minimum lot size, coverage, floor area ratio and density comprise the five regulations applied in the zone. The additional controls are focused on landscaping, use conditions, bulk controls and other regulations. Changes in the standard coverage value generate variation in the control but not spatially.

The majority of the regulations, three of the five, are orientated to be attributes rather than spatial representations.

5.2.17 eThekwini Special Zone Umgeni Business Park

There are four regulations in the Umgeni Business Park special zone, of which half can be displayed spatially. In the sample, eighty-eight parcels fall in this zone.

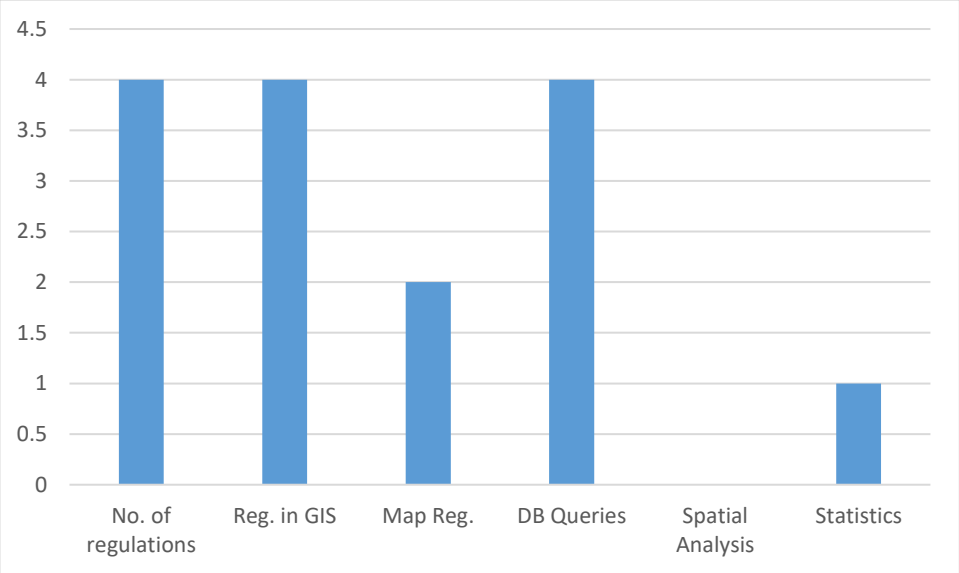

Figure 5.16: Umgeni Business Park zone regulation use

Development in the zone is controlled by height, minimum lot size, coverage, and floor area ratios. Similar to the General Industry zone, the height value is specified in meters as opposed to all other height regulations, which are measured in storeys. This will likely have implications for standard measurements.

There are twelve permissible land uses in the zone. Fuelling and service stations, as well as all other uses not precluded or specifically permitted, can be allowed with special consent. Of the twenty-six zones interrogated here, this is only zone where specific activities are prohibited.

The additional controls focus on bulk and other standards but create variation on four properties. Spatial representations can be generated from the regulations while all of the regulations can be added and queried in a GIS database.

5.2.18 eThekwini Special Residential 180, 400 and 900 zones

Apart from changes in the values of the regulations, the controls for the three special residential zones in the eThekwini municipality are the same. All three have seven regulations including building lines, side space, rear space, height, minimum lot size, coverage, and density specifications. As such, the three will treated together here.

In all three cases, the two permitted uses are residential dwellings or multiple unit developments. The special consent activities are complementary to residential uses and total twelve in all cases.

There are one thousand eight hundred and sixty-seven parcels in the sample that are zoned special residential 180 with seven zoned special residential 400 and forty-four properties zoned special residential 900.

All of the regulations can be accommodated in ratio and nominal fields and four may be used to generate map features.

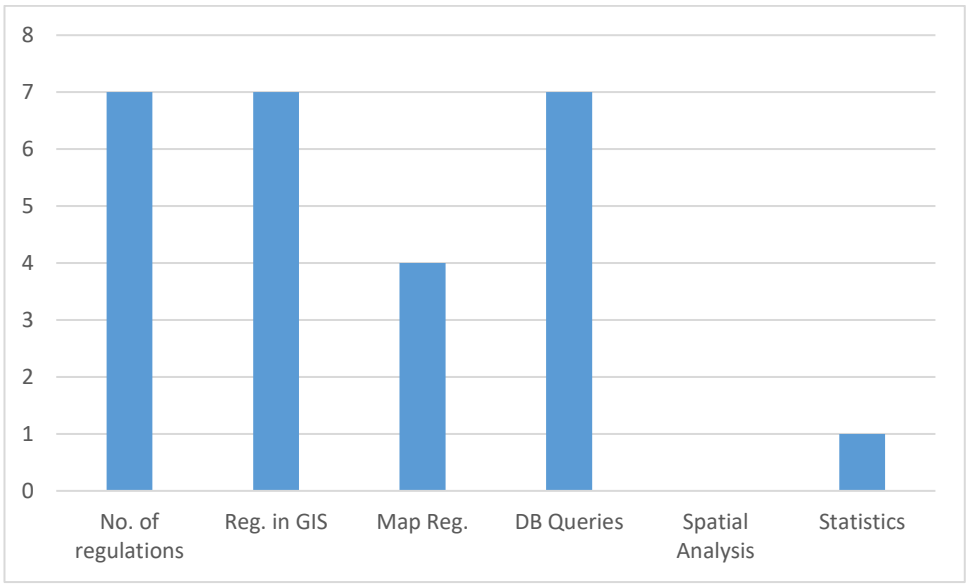

Figure 5.17: Special Residential zones regulation use

5.2.19 eThekwini Transport zone

All of the regulations in this zone can be accommodated in a GIS database and nearly all can be used to generate map features.

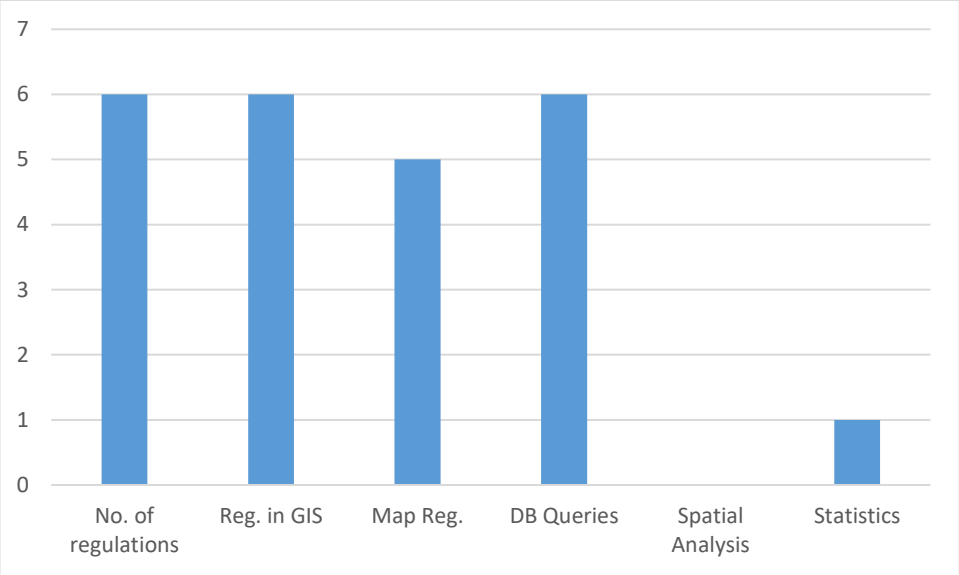

Figure 5.18: Transport regulation use

The Transport zone has seventy-two activities that are permitted with special consent. There are two uses that are permitted openly which include Government and Municipal, and Transport. The sample data contains forty-seven land parcels that fall in this zone.

The regulations total six and include building lines, side space, rear space, height, coverage, and floor area ratio. The height, coverage and floor area ratio do not contain absolute values but rather statements that they may not be higher than the highest flanking value. This has implications for standardising field values. The additional controls relate to landscaping as well as intent to rezone properties within the Transport zone, where current and projected activities are not transport-related.

Regardless of the present value statements in the height, coverage and floor area ratio regulations, half of the controls are nominal and the other half translate to ratio values.

5.2.20 eThekwini Worship zone

There are twenty-one properties in the sample database that are zoned Worship. The zone openly allows for three activities including a crèche, place of public worship and a dwelling for the clergy. An additional five activities are allowed with special consent.

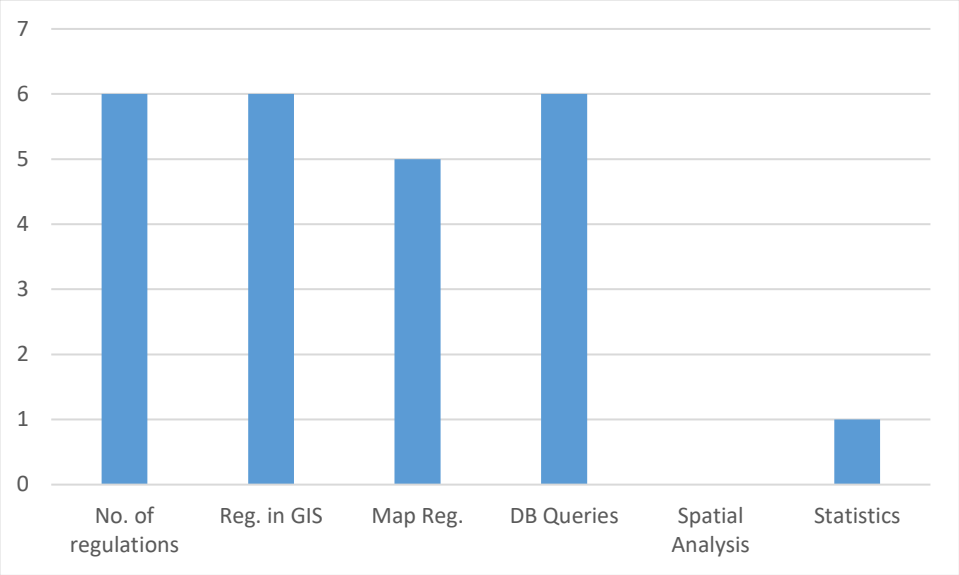

Figure 5.19: Worship zone regulation use

The standard regulations include building lines, minimum site size, side space, rear space and coverage. The additional controls not only add floor area ratio but create variety in both floor area ratio, which is set at "not applicable" for all but one property, and also coverage. The variation affects one property.

The nominal and ratio value data can be added to a database and all but one can be readily translated to map features.

5.2.21 Daufuskie Sub-urban Transect zone (D3)

The D3 zone is designed to accommodate residential and ancillary uses, including single family homes, home offices, bed and breakfast establishments, general commerce, entertainment and so forth. A total of twenty-one uses are permitted. With special consent, two more activities may be permitted. There are no uses that are explicitly precluded.

The nine regulations chosen for this interrogation include setback, side space, rear space, density, building archetype, public lighting, private frontage, building wall materials and windows and doors. Many additional controls exist but the types and values are the same as the above selection, for example, setbacks for the outbuildings or architectural standards for fences and garden walls.

The selected regulations translate to nominal data types. It should be noted that coverage also exists as a regulation in the code. While all of the regulations can be added to a GIS database, four can be used to generate map features other than labels.

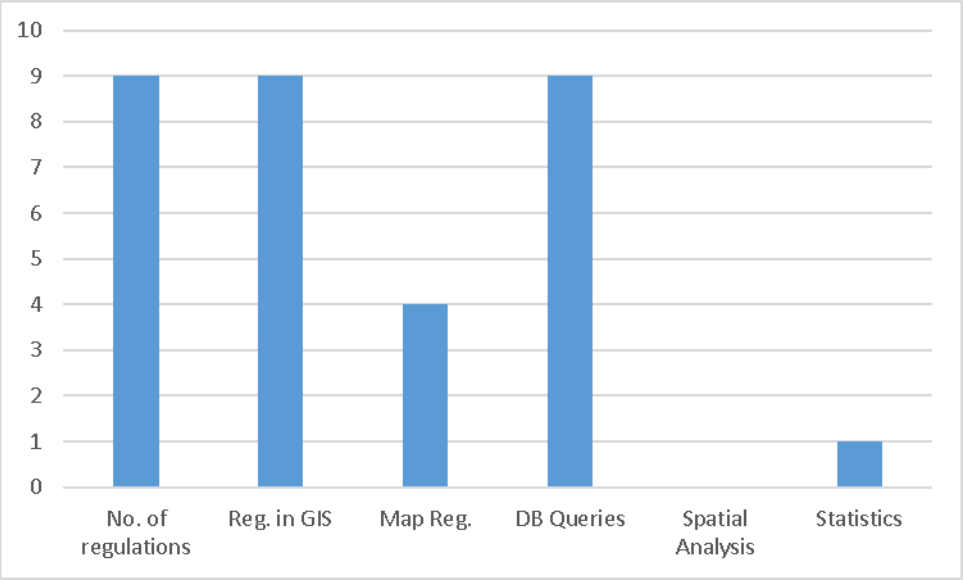

Figure 5.20: D3 zone regulation use

5.2.22 Daufuskie General Urban Transect zone (D4)

The selected regulations for the General Urban Transect zone are the same as those selected for the D3 zone although the values are different. In particular, the setback value for the D4 zone is variable, with a minimum of 12 feet and a maximum of 18 feet.

The permissible land uses in the D4 zone total twenty-one and include similar uses to the D3 zone although slightly more intense. For example, the D3 zone allows bed-and-breakfast activity while the D4 zone allows for an inn. There are no special consent or explicitly precluded uses in the D4 zone.

As with the D3 zone, all the regulations can be added to a database. Four of the regulations can be mapped.

5.3 Qualitative survey results

To gain some insight into the situation in the eThekwini municipality, the institution responsible for administering zoning in Durban, questionnaires were sent to the development planning department.

Of the twenty questionnaires sent, six persons responded. Half were GIS technicians and the other half indicated that they fell into a category other than the options available. Almost all the respondents had more than five years' experience with GIS. The graphs in this section depict percentage of responses.

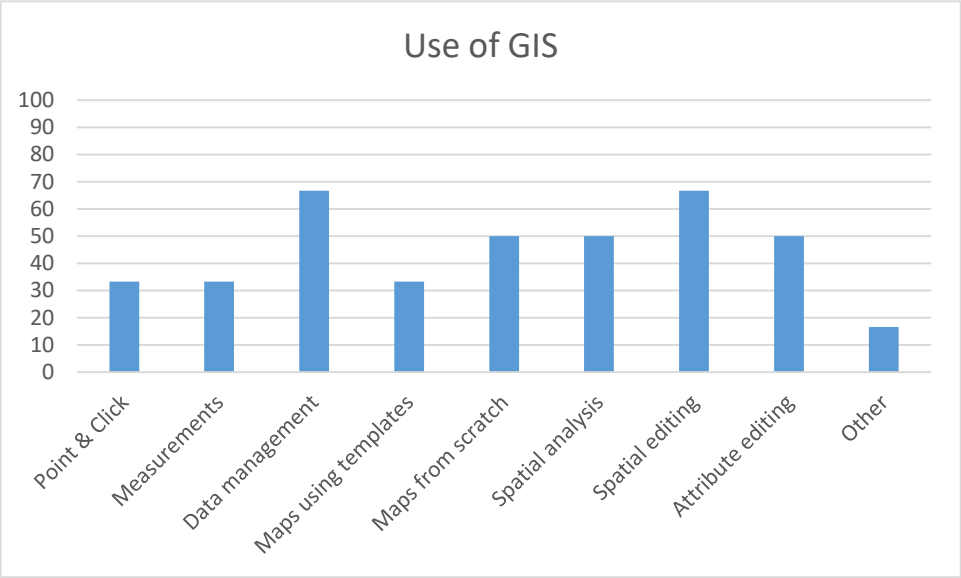

Figure 5.21: The ways in which GIS is used at the municipality

GIS is used in a variety of ways among the respondents. Data management and spatial editing were among the top uses. Half of the respondents used GIS for one function only while two indicated that they use the full range of functions.

Half of the respondents indicated that they had obtained a GIS qualification. Only one respondent indicated that he/she had developed GIS skills via more than one avenue.

Half of the respondents had obtained their skill at the workplace. Interestingly, none of the respondents had obtained their GIS skills at school.

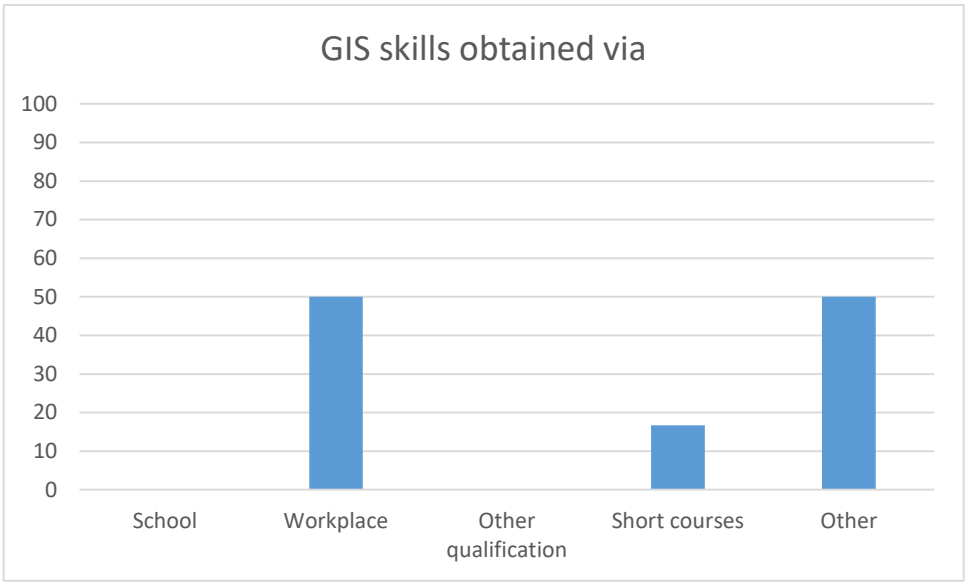

Figure 5.22: Indication of where GIS skills were developed

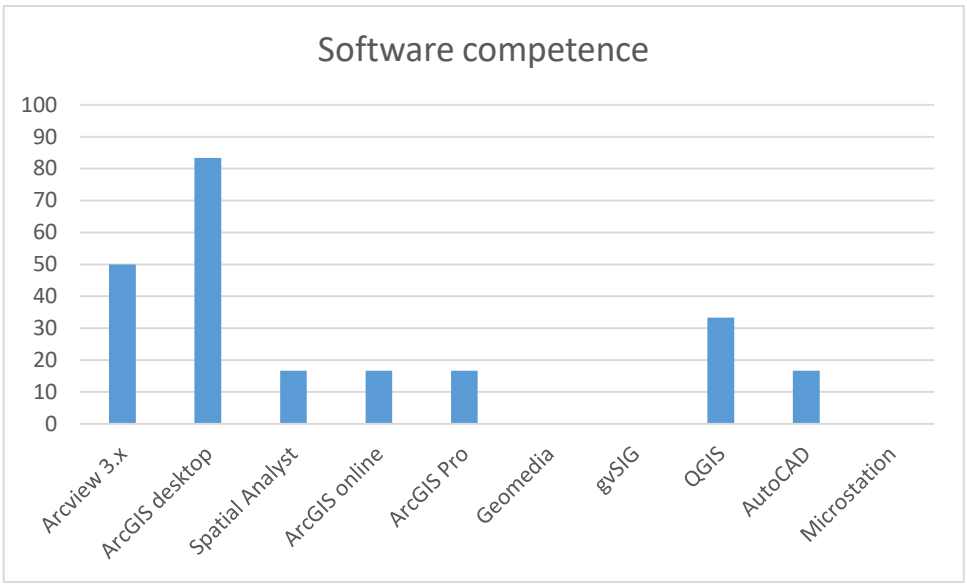

Figure 5.23: Software in which respondents believe themselves competent

It is not surprising that 83% of the respondents are competent in ArcGIS desktop since the municipality has a service contract with the Environmental Systems Institute (ESRI). Only one respondent believes him-/herself competent in the newly released ArcGIS Pro while half of the respondents indicated a proficiency in ArcView 3.x, a very old piece of software. One respondent indicated competence in six software

packages and three claimed competence in two software packages. It should be made clear that this competence is how the responded perceived themselves and no rigorous test was applied.

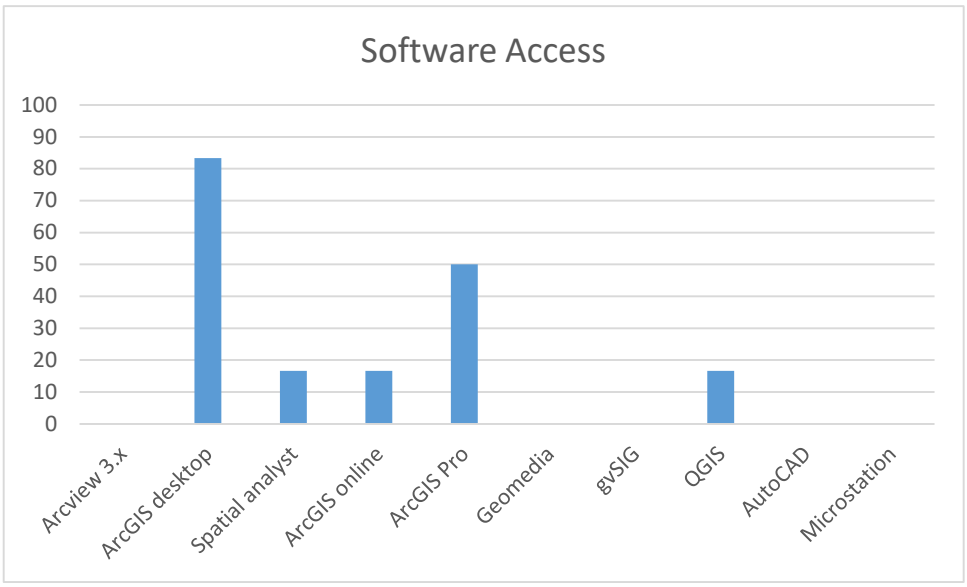

Figure 5.24: Software to which respondents have access

All but one of the respondents indicated that they had access to ArcGIS desktop. That one respondent was the only one with access to ArcGIS online. Respondents were divided about the institution's GIS skills, data and policies. Half considered the municipality's GIS skills, data and policies to be very good, the other half estimated it as being average. All respondents considered their own department's skills, data and policies to very good.

In terms of using zoning data, the majority of respondents indicated that they use zoning data several times per week, with half using it several times per day.

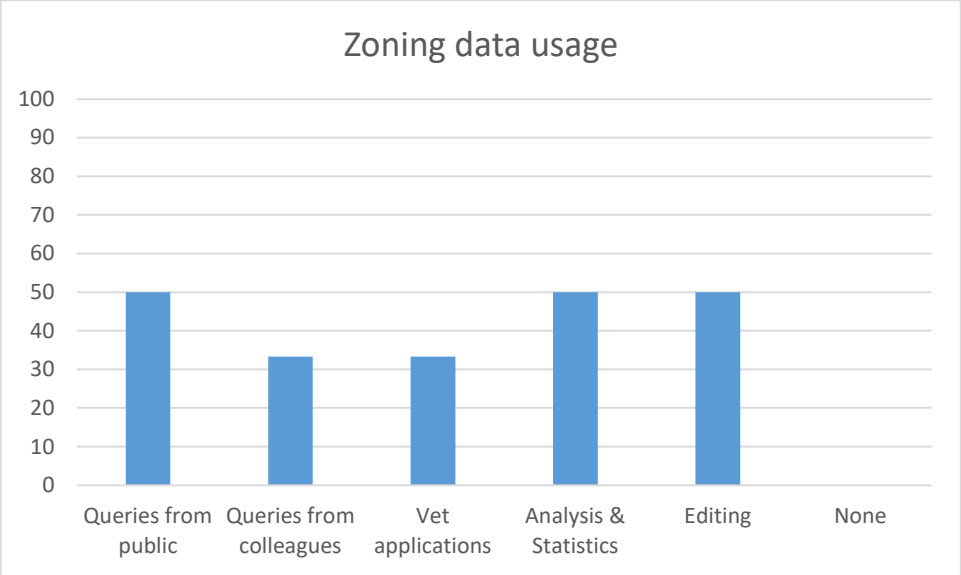

Figure 5.25: Zoning data usage

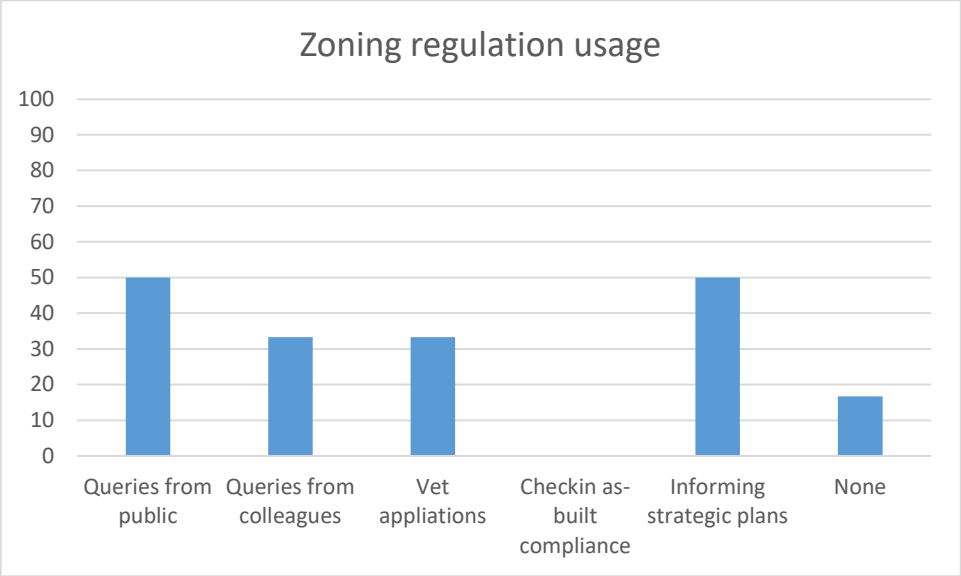

Figure 5.26: Zoning regulations usage

Only two of the respondents indicated that they have planning qualifications. Most of the respondents use zoning data and GIS to support processes in the municipality.

While all of the respondents believed that form-based codes should be used in the eThekwini municipality, only two knew that the code relates to building shape and placement rather than programming or systems.

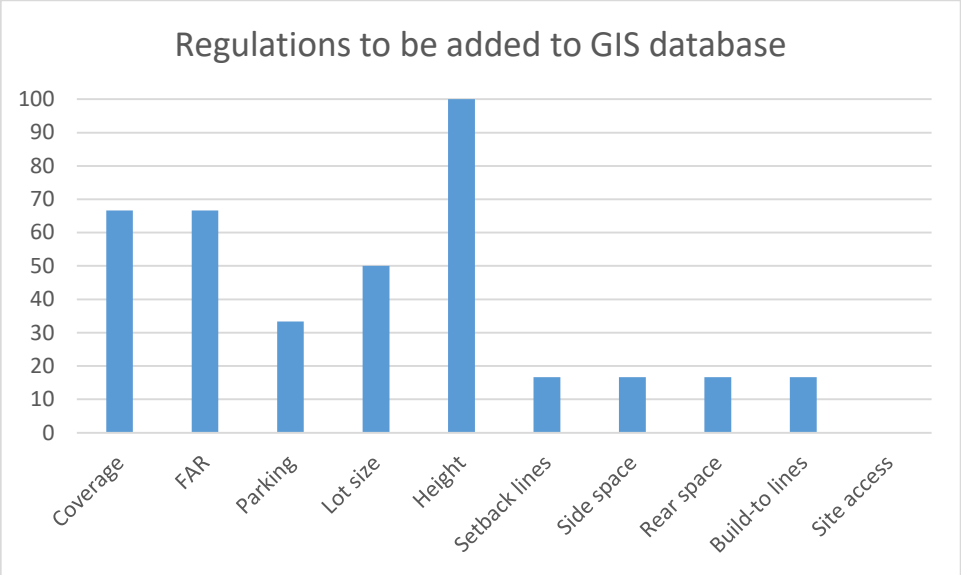

Figure 5.27: Regulations that the respondents thought of adding to the GIS

One respondent considered it appropriate to add all the regulations to the GIS database and one other respondent thought only building height should be added. All respondents considered building height important for the database and more than half thought FAR and coverage could be added. No one considered access to be a useful addition.

Two-thirds of the respondents believed it would be useful to show regulations on the map and to convert descriptive ratios to absolute values. The reasons provided for regulations not currently being in the GIS database included the recent move to by-laws creating uncertainty to not being a requirement.

5.4 Discussion of findings

The rational school of planning believes that more information will lead to better decisions (Dawwas 2014: 39), while the communicative planners believe that when information becomes embedded in thoughts and practices of communities, actions and assumptions are changed (Innes 1998: 56). The concern of advocacy planning with welfare and social justice resonates with the objectives of zoning and has endured (LeGates and Stout 2015: 427). Furthermore, some planners believe that misinformation is often not accidental (Forester 1982: 441) and that informing citizens early on is one way of limiting the effects of misinformation (Forester 1982: 445). There is also little doubt that zoning ordinances are difficult for the general public to

understand and that they are inefficient (Elliott 2012: 132). Taken together, these point to a need for better information that is communicated to the public better, earlier and more holistically.

Zoning schemes such as both the eThekwini scheme and Daufuskie code comprise of several sections. Conventional schemes typically include a map and separate textual regulations, definitions, procedures and people. eThekwini's scheme contains two hundred and one pages of regulations that sometimes apply to all properties and sometimes to only one. The Daufuskie Island code contains one hundred and ninety pages of regulations that apply to all zones and others that apply to some zones. Habermas's theory of communicative action requires certain conditions to be met for the ideal speech (or communication) with the first being comprehensibility (Ross and Chiasson 2011: 125). Forrester, similarly, states that for informed citizen action, comprehensibility, minimal technocratic jargon and intelligible information are requirements (Forester 1982: 444, 451). This all suggests that zoning should be provided in a format more accessible and digestible to the public.

Furthermore, the South African Constitution demands that local government promote a safe and healthy environment and encourage the involvement of communities in local matters (Republic of South Africa 1996: 74) and also make and administer by-laws for effective and efficient administration (Republic of South Africa 1996: 76). Regardless of the criticisms of zoning, the Spatial Land Use Management Act, No 16 of 2013 demands that all municipalities must have wall-to-wall zoning schemes (Republic of South Africa, 2013: 34).

There are two models for representing the geographic features. The raster model divides space into a series of rows and columns with an attribute at every location (Longley 2005: 72). The raster model tends to model natural phenomena well but does not represent man-made features well (Fazal 2008: 113). The vector model places spatial objects in a void. The objects are either points, lines or polygons, depending on their dimensionality, respectively either zero-, one- or two-dimensional (Longley 2005: 71). Land parcels are polygons which are lines connected to surveyed points in a closed circuit (Harmon and Anderson 2003: 92).

Zoning in formal systems are inextricably linked to legal land parcels. Vector data models represent man-made features better (Fazal 2008: 113) and as Helen Couclelis suggests, applications with the term management in them should typically use vector models (Couclelis 1992: 75). Zoning of course is a land use management tool and as such, a vector model is the proposed vessel for zoning.

The interrogation of the twenty-four zones reveals that ten unique controls, apart from use specifications, occur regularly in the eThekwini scheme. Six regulations occur more than 66% of the time. They include building line, side space, rear space, minimum lot size, height and coverage. Density and floor area ratios are used less frequently and floor area and access controls occur in less than 10% of cases (see Table 5.2 below).

The typical controls are also prevalent in the Daufuskie island's form-based code. Setback lines, side and rear space, coverage, height, densities, and minimum site sizes are among the typical controls. More detailed controls regarding the types of lighting poles, building wall materials, building placement and building topology also exist in the sampled zones of the code.

Table 5.2: Regulation prevalence

Zone	Building Line	Side space	Rear Space	DU/Ha	Minimum Size	Height	Coverage	FAR	Access	Floor area	Landscape AC
Cemetery	1	1	1	0	0	1	0	0	0	0	1
Creche	1	1	1	0	1	1	1	0	0	0	0
Educational 1	1	1	1	0	1	1	1	0	0	0	1
Educational 2	1	1	1	0	1	0	1	1	0	0	0
Educational 3	0	0	1	0	0	1	0	1	0	0	0
General Business 2	0	0	0	0	1	1	0	1	1	0	1
General Industrial	1	1	1	0	1	1	0	0	0	0	0
General Residential 1	1	1	1	1	1	1	1	1	0	0	1
General Residential 2	1	1	1	1	1	1	1	1	0	0	1
Indeterminate	1	0	0	0	0	0	0	0	0	0	0
Institutional 2	1	1	1	0	1	0	1	1	0	0	0
Institutional 4	1	1	1	0	0	1	0	0	0	0	1
Light Industrial	1	0	0	0	1	1	0	0	0	0	0
Petrol Service Station	1	1	1	0	1	1	1	0	1	0	1
Place of Worship	1	1	1	0	1	0	1	0	0	0	0
Special Residential 180	1	1	1	1	1	1	1	0	0	0	0
Special Residential 400	1	1	1	1	1	1	1	0	0	0	0
Special Residential 900	1	1	1	1	1	1	1	0	0	0	0
Special Zone: Umgeni business park	1	0	0	0	1	1	1	1	0	0	0
Special Zone: Greyville village	0	0	0	1	1	1	1	1	0	0	1
Special Zone: Atherton	1	1	1	0	0	1	1	0	0	1	0
Transport Zone	1	1	1	0	0	1	1	1	0	0	1
Suburban Transect Zone (D3)	1	1	1	1	1	1	1	0	0	0	1
General Urban Zone (D4)	1	1	1	1	1	1	1	0	0	0	1
Total	**21**	**18**	**19**	**8**	**18**	**20**	**17**	**9**	**2**	**1**	**11**
Percentage	**87.50**	**75.00**	**79.17**	**33.33**	**75.00**	**83.33**	**70.83**	**37.50**	**8.33**	**4.17**	**45.83**

The investigation of the sample cities also revealed setback lines, building lines, side and rear space, coverage and height regulations in more than 80% of ordinances. Floor area ratio, wall heights, parking, building form, frontage and minimum lot size controls occurred in more than 50% of cases. Regulations controlling landscaping and density were found less seldom.

All of the controls can be added to the GIS database as either nominal or ratio value fields. Nominal values are non-mathematical qualitative values used for describing features (Dale and McLaren 1999: 158; DeMers 2008: 29). Nominal values can be accommodated in the ArcGIS database as 'text' fields. The geodatabase feature class text-field limitation is set at 2 147 483 647 (ESRI 2020k) and as such can easily accommodate large texts. While all of the regulations could be depicted as nominal values, some are useful as rational values because they could be used to provide a clearer picture of what the regulation implies. Ratio values fall on a scale that has an inherent zero and for which differences between values makes numerical sense (DeMers 2008: 31). Coverage and floor area ratios, in particular, would be useful as absolute figures regarding the development envelope of property. Ratio values could be added to the feature class table as either 'short integers', 'long integers', single-precision floating points' or 'double-precision floating points' (ESRI 2020l).

Additional controls occurred in 100% of the zones, in both schemes. In the eThekwini scheme, the additional controls in particular focus on additional use conditions as well as other controls such as parking. Landscape and bulk controls also feature in nearly half of the zones (see Table 5.3 below).

Table 5.3: Additional control prevalence

Zone	Landscape AC	Bulk AC	Use AC	Other AC
Cemetery	1	0	1	0
Creche	0	0	0	1
Educational 1	1	0	1	0
Educational 2	0	0	1	1
Educational 3	0	0	1	0
General Business 2	1	1	1	1
General Industrial	0	0	1	0
General Residential 1	1	1	1	1
General Residential 2	1	1	1	1
Indeterminate	0	0	1	0
Institutional 2	0	1	1	1
Institutional 4	1	0	1	1
Light Industrial	0	1	1	1
Petrol Service Station	1	0	1	1
Place of Worship	0	1	1	1
Special Residential 180	0	1	1	0
Special Residential 400	0	1	1	0
Special Residential 900	0	1	1	0
Special Zone: Umgeni business park	0	1	0	1
Special Zone: Greyville village	1	1	1	1
Special Zone: Atherton	0	0	1	1
Transport Zone	1	0	0	1
Suburban Transect Zone (D3)	1	1	1	1
General Urban Zone (D4)	1	1	1	1
Total	**11**	**13**	**21**	**16**
Percentage	**45.83**	**54.17**	**87.50**	**66.67**

Additional controls are also prevalent in the Daufuskie Island code and include utility placement, walkway type, planter type and foundation specifications. The demands that the form-based code makes of the GIS are different from those of conventional schemes. In particular, the additional controls regarding building materials or garden fences are long-winded texts that will not fit neatly into a database format. Instead, these may be stored in the database as hyperlinks or attachments. Hyperlinks are path-links that can be stored in a database field to open a document outside the GIS environment (ESRI 2020j). Attachments are similar to hyperlinks but the documents are stored inside the geodatabase (ESRI 2020b).

The investigation of the sample cities also revealed additional controls in the global city schemes. The controls included ‘outside living space areas’, ‘apartment floor space’, ‘ceiling heights’ and ‘driveway dimensions’ to name but a few. Some of the schemes were simple with few regulations (Cape Town and Hong Kong) but others were complex with many controls (Christchurch, New York).

While all the prevailing controls can be added to the GIS database, the more complex ordinances would require effort to ensure that the database remain logical. The geodatabase can accommodate up to 65 538 fields, implying that a large amount of structured regulations could potentially be accommodated. Variation within the zone refers to instances where the standard control is changed by additional controls. For example, a height of two storeys is permissible for a zone but the additional or other control sets the height regulation for property *x* as three storeys.

The table below indicates a total twenty-four instances where the standard control is changed in the zones interrogated here and how many parcels are affected. This has implications for assigning controls to parcels in the database. While assigning attributes can be largely automated, the instances where the controls are varied require manual editing.

Table 5.4: Variation within zones

Zone	Instance	No. of parcels
Cemetery	0	0
Creche	0	0
Educational 1	0	0
Educational 2	0	0
Educational 3	1	1
General Business 2	3	3
General Industrial	0	0
General Residential 1	2	30
General Residential 2	2	4
Indeterminate	0	0
Institutional 2	4	16
Institutional 4	0	0
Light Industrial	3	12
Petrol Service Station	1	1
Place of Worship	2	2
Special Residential 180	1	0
Special Residential 400	1	7
Special Residential 900	1	7
Special Zone: Umgeni business park	2	8
Special Zone: Greyville village	1	1
Special Zone: Atherton	0	0
Transport Zone	0	0
Total	**24**	**92**

Variations were also commonplace among the sample cities. London in Canada had one hundred and seventy-six variations within the ‘Residential R1 zone’. Christchurch had sixty-nine variations to controls in the Residential Suburban Zone and the Residential Suburban Density Transition Zone; however all the zones checked, in all the schemes, had some variable controls specified.

Although important for local context and protection, the variations aid in making the ordinance messy and difficult to navigate. This leads to the question of whether it is better to assign regulations to zones or to land parcels. Assigning the controls to individual parcels would remove the need to refer to additional controls hidden in the ordinance. Given that the geodatabase can contain up to 2 147 483 647 (ESRI 2020k) records, all land parcels in a city could be accommodated. Also, controls could be assigned in a semi-automated manner using table joins. The variations would have to be edited manually, but in the twenty-two eThekwini zones interrogated in this study, twenty-four variations affecting ninety-two parcels were found. There are four thousand four hundred and thirty parcels in the sample suburbs, which means that, if all the variations were within the sample data, 2% would require manual editing.

It should be noted that all regulations could be shown as labels or part of a label on the map.

Building line, side space and rear space controls can be stored both spatially and non-spatially in the GIS database. The attribute describes the location of the line feature in relation to the front boundary, side boundaries or rear boundary of a land parcel. The line would be within the land parcel and need an intermediate user to capture it. The line could be created using an offset function in a CAD or GIS environment. The field type for the description would be nominal, a text field. While the spatial capture would be tedious, the majority of attributes could be assigned automatically by using a table join function in GIS. Where variations within the control exist, manual rectification is required.

Height can be stored as an attribute. With some zones using storeys as the measure, other zones using meters and still other regulations specifying angles, the field type for height must be nominal, text fields. An additional field could be created with an estimated height value in either meters or storeys.

Floor area ratio can be both spatial and non-spatial. In this case, the attributes regarding zoning controls are attached to a land parcel polygon. The polygon boundary could be used to reflect the floor area ratio as a graduated symbol instead of generating new geographic features. The cartographic polygon can be offset from the real

boundary so as not to interfere with or be obstructed by the boundary line. The attribute field could be either nominal or ratio in the form of, respectively, text or double. An additional field could reflect the absolute permissible floor area which could be derived by multiplying the area of the polygon by the floor area ratio.

Coverage can also be reflected spatially and as an attribute. As with floor area ratio, coverage could be displayed as a graduated symbol, offset from the boundary line. The attribute field could be either text or double. An additional field could be added to reflect the absolute value of permissible coverage. This would be derived by multiplying the area of the polygon by coverage.

Even though access appears only twice, it should be included in the GIS database. It can be represented spatially as a line along the boundary of a property to highlight the constraint. Additionally, it can be stored as an attribute of the relevant properties as a nominal value.

Only one instance of floor area control was found in the sample. Floor area controls can be stored as attributes of the relevant properties. The field could be either a nominal or a ratio value. The low frequency implies that attribute entry will be manual.

Density controls can be stored as attributes of properties affected by the regulation. The field type will be descriptive but an additional field could be added to reflect the potential number of units for each parcel. The eight instances all reflect different densities, which would require selecting each unique control before permissible floor area could be used to calculate the potential number of units. The ‘potential units’ field should be a short integer type.

Minimum lot size can be stored as a nominal or ratio value attribute. A ratio value attribute may be used to determine non-compliance by comparing it to the area of the polygon. As with most of the other attributes, a table join function could semi-automate the assignment of values to the GIS database. Where there is variance, manual edits could be made to the database.

While the additional controls are often large bodies of text, attributes that prompt further investigation could be added to the database. The additional controls typically treat usage conditions, landscaping requirements, specific bulk regulations or other controls such as parking. Fields that indicate additional controls in any of the four categories may also be added to the map as markers or point features. Document hyperlinks or attachments linking to the scheme page related to the zone could be added for the user to access the additional controls.

Given that most people can learn spatial concepts easily (Montello 1995: 496), that graphic norms are considered a valuable addition to legislation (Moroni and Lorini 2017: 15), and the need for providing information in the most understandable manner to the public (Forester 1982: 444; Ross and Chiasson 2011: 125), setbacks, building lines, and rear and side space can be used to generate new line features that could be shown on the map. The regulations specify a distance, in each case, from the property boundary where development may not occur. This means that the lines can be generated using an 'offset' command in GIS or CAD. The offset function in ArcGIS (ESRI 2020f) is much more cumbersome that the same function in AutoCAD (Autodesk 2020), so the property data will be exported to CAD using the 'Export to CAD' function (ESRI 2020e). The attribute, distance from property boundary, can be exported as text using the 'Export attributes as CAD text' function (ESRI 2020d). Once the lines have been created, the layer can be imported into the geodatabase as a line feature class and be made topologically correct by using the 'intersect' tool (ESRI 2020h) along with the parcels layer.

The majority of functions needed to include the regulations in a GIS database would require intermediate skill. In most cases, the preparation of tables that contain the zone name and specific control would allow for a table join function with the parcel containing the zone name and empty field for the specific control. A one-to-many relationship between the tables would be established and the field in the parcel database would be populated with the attached tables' values. If variance in the control exists, those properties would have to be edited manually.

A few issues may complicate the process or need to be kept in mind. There is variation between the scheme and the database. Several zones are not in the regulations

including Existing Street, Extended Residential 650, General Shopping, Government and Municipal, Maisonette 650, Maisonette 900, Minor Shopping, Mixed Use, New Street, Office, Public Open Space, Special Residential 650, Special Shopping And Special zone Springfield Road. This implies that the database will not show any data for properties in these zones. Furthermore, the names of zones in the database and the scheme do not always match. For example, the Fuelling and Service Station zone is referred to as the Petrol Service Station in the database, while the Worship zone is referred to as Place of Worship in the database. The scheme also assigns zoning to leased land which does not form part of the cadastre. This implies that these may have to be added to the cadastre using a topological overlay union function. If the leased land is simply drawn on top of the cadastre, spatial analysis results would be incorrect. Similarly, environmental management overlays zones must be considered as these will impact on permissible floor area calculations.

5.5 Conclusion

The qualitative survey results showed that the use of GIS in the sample was varied across the range of functions of a GIS. The majority of officials had access to and used ESRI's ArcGIS Desktop. This would imply no hindrance in moving from shapefile to geodatabase feature classes.

The questionnaire results also indicated a limited interest in moving all the regulations to a GIS database with only typically textual regulations being suggested for inclusion in the GIS. This may provide some indication of why the move from textual documents to the GIS has not been forthcoming.

The small size of the team of officials allocated to working with GIS and zoning may be a further indication of the lack of importance ascribed by the municipality to this endeavour.

Findings of the quantitative assessment show that all the regulations could potentially be added to the GIS in one form or another. Most of the regulations in conventional schemes could easily be incorporated as attributes to zones or parcels. Some of the regulations, such as building lines, also naturally lend themselves to spatial

representations on a map. The regulations in form-based schemes are more complex with, in many cases, detailed descriptions of form, building materials or styles.

The quantitative assessment furthermore shows that there are several regulations for each zone dealing with usage and form. On top of that, there are variations within each zone allowing for site-specific regulations. There is an argument here for parcel, instead of district-based, zoning in order to reduce complexity and ambiguity.

Chapter 6. Final conclusion and recommendations

6.1 Introduction

This study set out to prove the hypothesis that GIS can be used to make the transition from paper maps and separated regulations to a digital GIS environment. Several sources (United Nations 2015; World Economic Forum 2015) suggest that the sub-Saharan urban population will expand at the fastest rate in the world over the coming decades. The need to manage cities effectively and efficiently is ever-increasing. Similarly, the need to communicate with urban populations in a transparent, effective and comprehensible manner increases as urban populations grow. The Internet and smartphone applications are growing the public's access to information of all sorts. Currently, there are between twenty and twenty-two million smartphone users in South Africa and this is expected to grow by five million in 2023 (Statista 2019).

To date, zoning has mainly been kept at municipal offices as a map and a separate text document. Where the zoning information is shared with the public via web-maps, only the descriptive name of the zone is made available. Using GIS, the controls and regulations can be added to the database in a structured, logical manner and be disseminated to inform the public. While zoning on the one hand restricts or regulates what a property may be used for and how it may be developed, it also implies development rights to the property.

The Constitution of South Africa demands that municipalities provide safe and healthy environments for its citizens, which resonates with the objectives of zoning. The Constitution also requires municipalities to develop by-laws for the efficient and effective management of urban areas. The Spatial Land Use Management Act, No 16 of 2013 (Republic of South Africa 2013) furthermore demands that all municipalities zone all land within their jurisdiction.

Zoning is also a powerful tool and it has been argued that it has a greater impact on property value than public plans, coalition building , strategic plans and more put together (White and Allmendinger 2003: 955). Public choice theory, Bent Flyvbjerg's studies in Aarlborg, Habermas, Foucalt and Forester all suggest that the public

servants who wield zoning power amongst other things, often abuse their position for personal gain. Habermas and Foucalt agree that the misuse of power and rationalisation is one of the great problems of our time (Flyvbjerg et al. 2002: 54,55) and Forrester suggests that a key measure to counter this, is to inform the public early on (Forester 1982: 445).

Informing the public must be done in a comprehensible and complete manner. By supplying zoning regulations with the map, the use of GIS improves the process. In fact, having access to the information on a platform where cross-referencing and multiple perspectives can be attained, changes the map's communication from a static representation to a process (Crampton 2001: 244). This process may, as the communicative planners believe, impart knowledge that will change the way in which communities behave and reach consensus for the better (Innes 1998: 56).

6.2 Research question 1: Planning and GIS theories

The two geographic models which are universally used to represent spatial features are called the raster and vector models in computer terms. The raster model divides space into an array of cells where each cells value records whether it is part of the theme or not. Raster systems portray natural and continuous phenomena well but do not work particularly well with man-made features. The vector model represents geographic features as objects in space. These objects can be either points, lines or polygons depending on their dimensions and each has a record of attributes attached. Land parcels are typically represented as polygons which are two-dimensional objects comprised of lines that are connected to surveyed points. Globally, zoning is applied either to land parcels or to larger zones wherein land parcels are located. A principally vector model with raster aids is therefore ideal as the vessel for zoning.

Not unlike the long-running raster-vector debate, planning theories have for many years argued for which approach is the best. Because of the large variety of popular planning theories, the approach to planning theory today is more pluralistic, realistic and flexible (LeGates and Stout 2015: 427). Rational planning, which has been around since the early twentieth century, developed at around the same time as zoning and the two are very much linked. Similarly, GIS, which has been criticised as positivist, is rational and loaded with Boolean logic. The rational school believes that more and

better information will lead to better decisions. Amongst other tasks, planners also negotiate, mediate and resolve conflict between different factions (LeGates and Stout 2015: 427). The communicative planners attempt to improve social understanding and consensus through communication. They believe that when information becomes embedded in the thoughts and practices of a community, it changes actions, problem definitions and assumptions (Innes 1998: 56; Innes and Booher 2015: 202). Thus, providing comprehensive and comprehensible zoning information to the public may lead to positive change. Advocacy planning is concerned with social justice. Paul Davidoff and others started the movement in response to the perceived failures of rational planning. The movement has endured and still influences planning (LeGates and Stout 2015: 427). Advocacy planning echoes the objectives of zoning even though many abuses have occurred over the past hundred years. The youngest planning theory is New Urbanism, according to which form-based codes have emerged as a different type of zoning. The movement, which incorporates many dimensions of the preceding theories in planning, aims to redress the fragmented, sprawling fabric wherein social disconnection has, since the Second World War, become ubiquitous. They aim to do this by designing spaces that focus on the public realm, mixed uses that promote pedestrian use, multiple modes of transport and sensitivity to the environment, amongst other things. Form-based codes are set up similar to typical ordinances with maps, regulations, definitions and procedures. They do offer many more graphic elements. Form-based codes are novel in the South African context but may have a role to play in setting standards for the public realm and informal settlements.

The communicative planning theory is loosely based on Habermas's theory of communicative action (Innes and Booher 2015: 199). Habermas contends that consensus between stakeholders may be reached in a rational manner. The concept of a communicative rationality is comprised of open strategic action and hidden strategic action. Open strategic action is welcomed but hidden strategic action is detrimental to reaching consensus. This open strategic action is akin to transparency, which is one of the ways to circumvent strategic misinformation or power abuse.

In order for consensus to be reached or for real communication to take place, there are validity rules that must be adhered to. They include truth, truthfulness and legitimacy (Ross and Chiasson 2011: 126). Forester puts it into planning terms as the need for

comprehensibility, sincerity, legitimacy and accuracy, which translate respectively to minimising technocratic jargon, building public trust and avoiding manipulation, obtaining public consent, and providing information that is accurate (Forester 1982: 444). Comprehensibility is a foundation that must be attained before Habermas's validity rules can be considered. Most schemes are not comprehensible but rather inefficient and difficult for the public to understand (Elliott 2012: 132), suggesting that a change is required.

While Habermas pays little attention to the power aspect of the lifeworld, Foucalt suggest that power is everywhere and that strategic engagement with power is the only way ensure that it is kept in check (Flyvbjerg et al. 2002: 55).

Zoning is a tool used in land use management. The purpose of land use management and schemes is to promote health and safety, environmental quality, convenience, energy conservation, social equity and amenity (Briginshaw, D. M., Kahn, M., Ferguson, C. A. C. 2011: 3). This is almost identical to typical zoning objectives such as promoting health and safety, order and general welfare, promoting integrated and sustainable development; conserving and protecting environmentally sensitive areas, and promoting all forms of development and growth according to planning principles (eThekwini Municipality 2016: 7).
The schemes are usually of similar composition and have maps and text documents that contain the regulations, definitions and procedures.

6.3 Research question 2: What demands does conventional zoning make?

The interrogation of the twenty-two eThekwini zones and the zones from the six global cities revealed very similar controls. Almost all could be described as nominal values although some are useful as rational values. All could be incorporated into a GIS database as attributes of land parcels. The regulations included floor area ratios, coverage, height, building line, side space, rear space, density, minimum lot-size, access and floor area. Some of the regulations could be used to generate map features or graphic norms such as building lines and side and rear space. New database formats mean that size limitations of the past have become almost irrelevant and as such large bodies of text or scanned images can be stored in the database.

All of the schemes investigated had some variation in the form of additional controls that complicate the scheme. These additional controls or variable controls are important to address local concerns and contexts. The choice to use a parcel-based approach where each parcel is assigned its own control implies that the variable controls are not required.

Other parts of the scheme such as the definitions are also crucial to the comprehensibility of the ordinance. Portions of the scheme can be linked to the database using either hyperlinks or as attachments in the database.
Management overlay zones and split zones appear to complicate things but are addressed by the parcel-based approach where each parcel is treated individually.

The definition of side and rear space on irregular shaped polygons is another complication but if an official determines and communicates the decision on a map this complication is eradicated.

6.4 Research question 3: What demands do form-based codes make?

While the Daufuskie Island code was the only full form-based-code this study interrogated, the Christchurch and Dublin schemes also showed hints of form-based controls. As with the conventional zoning, most of the controls can be considered nominal values with some being useful as ratio values.

Unlike conventional zoning, the form-based-code contains much more graphic guides and regulations. As such, apart from the database attributes, images and or document attachments are required more.

The attachments should also include definitions and instructions to ensure that all the scheme information is available at a single source. Attachments can also be used in ESRI's web mapping applications.
It is imperative to note that for both types of scheme, typical database rules must be applied. This includes not leaving cells empty when a particular regulation is not applicable. For such cells, a value such as "Not Applicable", "N\A" or "-99" should be used.

6.5 Research question 4: What model can be used?

As has been mentioned, the vector model is more suitable for representing man-made features such as land parcels. Thus, the model proposed is comprised of primarily polygon and line features, tables containing controls and ratio values and supporting features and documentation. Figure 6.1 below is a diagrammatic representation of the basic model.

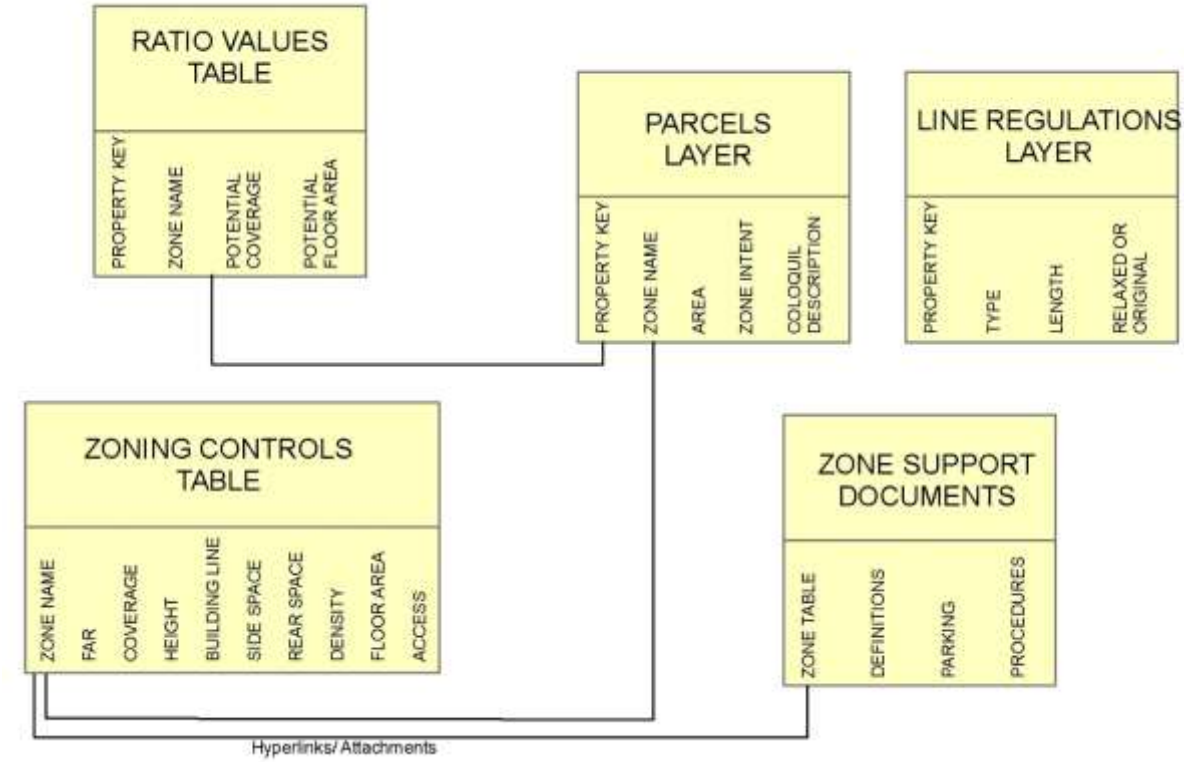

Figure 6.1: GIS model

Since the eThekwini municipality uses ESRI ArcGIS software, the template can be incorporated in the geodatabase which would allow large volumes of data if necessary as well as features such as attachments.

As was found in the eThekwini scheme, the Daufuskie code and the investigation of the sample cities from around the globe, a typical scheme has a scheme map with only the zone name (or sometimes, code name) depicted. The regulations are kept in a separate text document.

Figure 6.2: Typical view of zoning map

One of the recommendations made here is to add whichever controls are possible as graphic norms to map. Building lines, side space and rear space are naturally suited to be displayed graphically. This means that a user can visually see what the controls imply and officials can potentially evaluate proposals or as-built conditions for compliance. See Figure 6.3 below.

Figure 6.3: Graphic norms added to map

Dynamic labelling of features on the map draws the information for the label directly from the attributes of each record. This means that if the information in the attribute table changes, the label also changes. Typical zoning maps may have the property

description as a label on the map. Visible scale ranges, label classes and multi-line labels can be employed to provide more or less detailed labels regarding the parcel. Visible scale range settings allow labels to be shown, or not, depending on the scale of the map. Label classes allow the same feature on a map to display different labels, depending on conditions such as the scale of the map or the size of the property. ArcGIS has functionality that allows for multi-line labels which contain text descriptions and real values. Figure 6.3 below shows labels on the pre-test map where smaller properties show less information and larger sites, more.

Figure 6.4: Zoning map with dynamic, multi-line labels

Apart from labels on the map, all the controls are stored in the attribute table and can be accessed at any time, at any scale. The pre-test model also shows that no field is left blank which may indicate an error or misinformation.

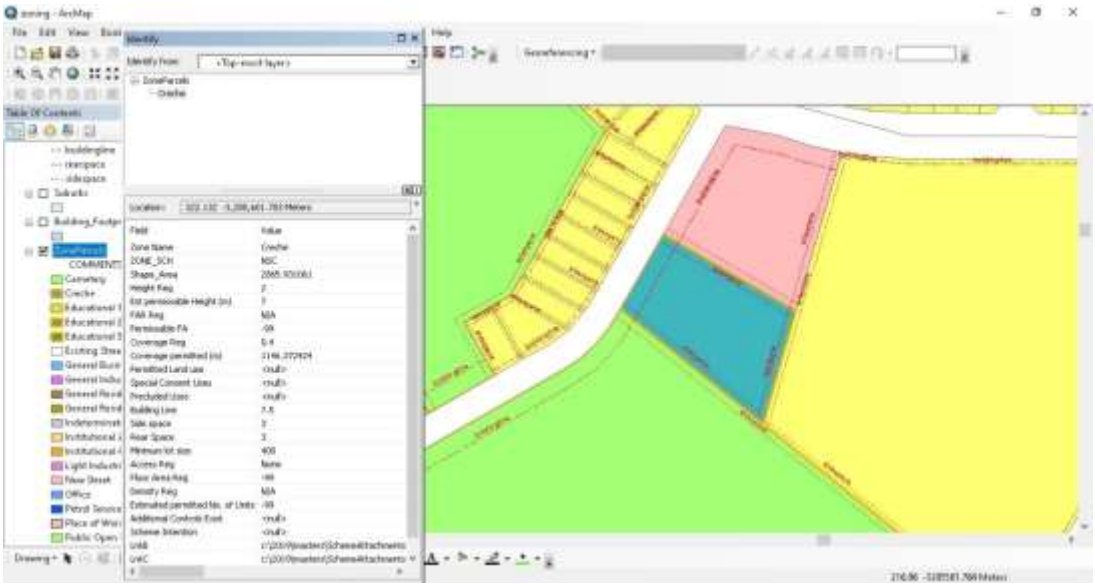

Figure 6.5: Map with all controls and conversions, as attributes, visible

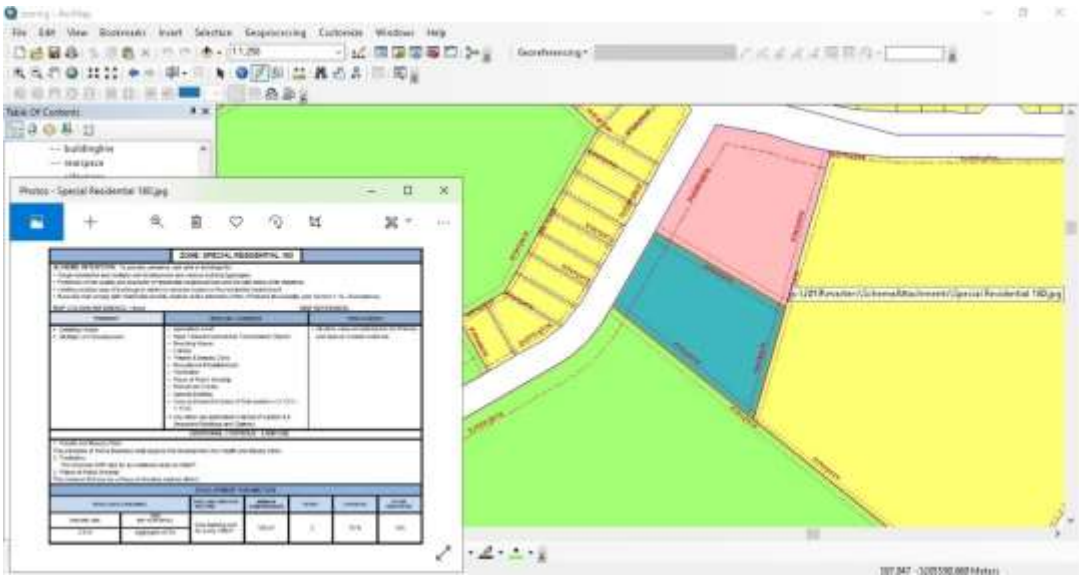

Figure 6.6: Map with hyperlinked controls

Hyperlinks can be used to link to documents stored outside the GIS environment. These documents could be any part of the scheme document and in any format. In Figure 6.6 above, the hyperlinked support document is the regulations for the ‘Special Residential 180’ zone. In the pre-test model, a hyperlink field was added and populated by assigning the path to the various zone pages along with the zone name.

Each zone page was given the name of the zone, for example, ‘Special Residential 180.jpg’. It must be noted that only one hyperlink field can be set in ArcGIS, implying that only one supporting document can be accessed. Since form-based codes require more graphic attachments, it may be more appropriate to use the ‘attachment’ functionality in ArcGIS rather than hyperlinks. Multiple attachments can be made for each zone. This means that the scheme could be split into its various sections and each attached.

Apart from showing labels for each property, the ‘dissolve’ function could be employed to generalise the land parcels dataset, based on any of the attribute fields in the database and zone labelled or shown as unique value descriptions. In the pre-test model, the parcels were dissolved, based on the FAR field and displayed and dynamically labelled.

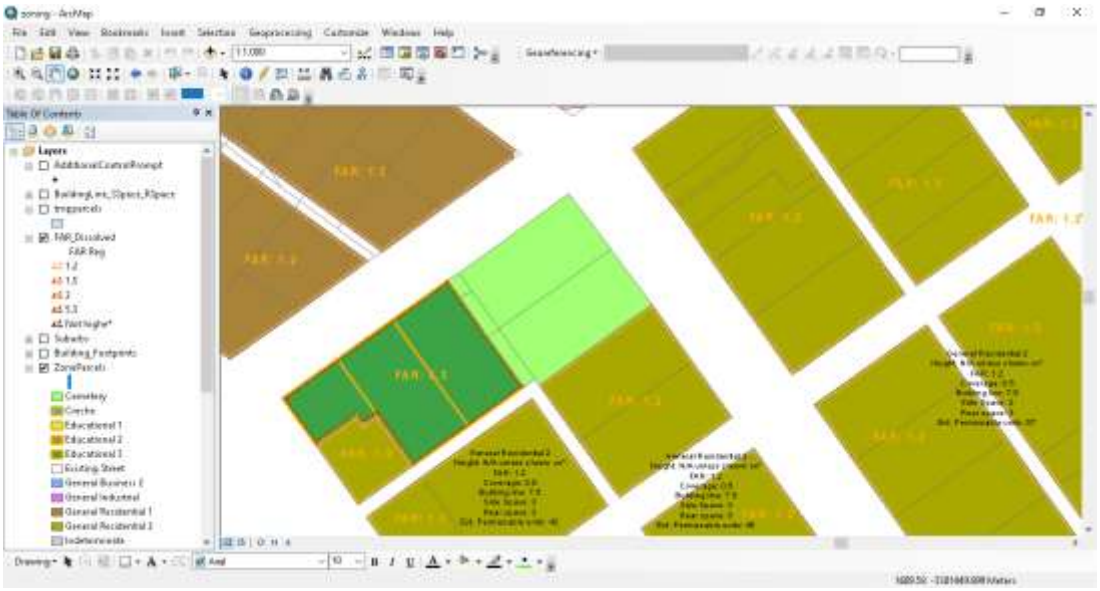

Figure 6.7: FAR shown as dynamic labels in dissolved zones

6.6 Value added by study

By adding graphic norms to the map for building lines, side and rear space, it is believed that these controls and their implications become more comprehensible, which is a key foundation for improved communication. It also means that officials could more efficiently vet proposals or perform as-built compliance checks.

One of the most inefficient aspects of ordinances in their current form is the separation of regulations from the maps. Having the controls as attributes to parcels or zones

allows access to the regulations at the click of a button. Having access to the regulations is cornerstone for communicating with the public regarding the management of land and their development rights. While the eThekwini scheme and all the other ordinances interrogated in this study were found on the Internet, simplifying the process by connecting map to regulations with controls in the database and hyperlinks to ordinance regulations, improves access.

In this study, half of the schemes investigated use districts and the other half use land parcels as the vessel for regulating. The eThekwini scheme uses land parcels and Daufuskie Island uses transect zones. While it is not new to use parcels, the pre-test model and interrogation of the various scheme regulations suggest that the use of parcels removes complexity of the scheme by removing variables within each zone. Furthermore, management overlay zones and other regulations attached to but not directly in the scheme have an impact on the development rights of properties and should be incorporated at a parcel level.

Finally, converting the nominal regulations to ratio values in database show officials and public the total potential development right of any property or block of properties, at the click of a button. For example, an FAR of 5.3 on a property with an area of 2570m2 equates to a potential 13 621m2 of permissible floor area. Currently, this has to be calculated each time there is a query. For blocks of properties the task increases. Real floor area and coverage values have immediate implications for infrastructure and services. Also, the converted values allow for what-if scenarios to see how proposed changes to zoning may impact on a property or block of properties.

6.7 Recommendations

It is recommended that this approach be implemented across the whole municipality and all the zones to better communicate the city's land use management and development controls to its citizens, particularly in the light of SPLUMA and the intention to zone those areas where zoning has not been used in the past.

The dataset must be disseminated on a municipal GIS web-map. While the zoning layer already features on the web-map, it only depicts the zone name. By divulging the controls and regulations with the map, the municipality will open access in a

comprehensible, efficient manner. As a part of this, the intention of scheme, which is stated in layman's terms, should be added to the map as a note. Examples of simplified explanations of the zone intention were also found on the New York City map and the Christchurch map.

The Cape Town website had instructions and a link to zoning on the disclaimer page (the first page to the map). It is recommended that this become a norm not only to draw attention to zoning but also to create opportunities to educate the public.

6.8 Potential future studies

This study highlighted a couple of issues that could potentially be investigated and studied in the future.

Cities around South Africa, including Durban, all have continuously burgeoning informal settlements, and since sub-Saharan Africa is expected to continue urbanising rapidly over the next few decades, informal settlements will continue to exist and grow. While zoning *per se* is unlikely to be effective in managing land use in these settlements, the objectives of zoning and form-based codes could be applied and enforced to create safer, better quality environments. Study into how zoning objectives, which protect citizens, and form-based code's preoccupation with delivering a better public realm, may be applied to informal settlements, may be worthwhile.

While interrogating the eThekwini scheme, it was noted that some zones did not have accompanying regulations. Further study regarding missing regulations for public properties such as municipal and government, public open space and road reserves may be important for transparency, accountability and credibility. Given the assertions of public choice theory, Bent Flyvjberg's Aarlborg study findings, Habermas and Foucalt's agreement that misuse of power is one our time's greatest problems, and the well-documented corruption in South Africa, a tool as powerful as zoning must be used fairly and transparently where all parties are accountable. It may be that those zones are regulated elsewhere, such as at provincial level, but further study is required.

Another anomaly noted during the study was mismatches between the scheme and the existing GIS data. In some cases the name of the zone was different, for example, the scheme uses ‘Fuelling and Service station’ while the GIS data uses ‘Petrol service station’. In other cases the GIS data contains zones which are not in the scheme document. These are zones that are not suspect as above but appear to have been usurped by other zones, for example the ‘Maisonette 650’ zone. It may be worthwhile to investigate the scale of the mismatch and to identify the reasons in order to provide accurate, credible information to the public and officials.

Finally, while the database in its current form can be queried to see the potential developable floor area or coverage, what-if scenarios still require manual changes or calculations. Further study may look at the development of a software tool with which to quickly test the implications of zone changes. As mentioned above, changes to the floor area or coverage have implications for service delivery, infrastructure, traffic and more. ArcGIS Modelbuilder could be used to work seamlessly with the geodatabase.

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ANNEXURE A: GATEKEEPER LETTER

SUSTAINABLE DEVELOPMENT & CITY ENTERPRISES
Development Planning, Environment & Management Unit

166 K E Masinga Road, Durban, 4001
P O Box 680, Durban, 4000
Tel: 031 311 1111, Fax: 031 311 7776
www.durban.gov.za

Date

Mr J. Kitching
Town and Regional Planning department
Durban University of Technology
Master of the Built Environment Student: 19551326
e-mail: gis@dut.ac.za

Dear Mr. Kitching,

PERMISSION TO CONDUCT RESEARCH

Gatekeeper's permission is hereby granted for you to conduct research among the staff of my department at the eThekwini municipality towards your postgraduate studies, provided that ethical clearance has been obtained. We note that your research project is:

"Geographic Information Systems as a tool for the representation of zoning controls".

It is noted that you will supply us with questionnaires, information letters and consent forms at a time convenient for either me or an appointed subordinate. A copy of this letter (gatekeeper's approval and ethical clearance must be provided before any research may be conducted. A date for collecting the completed questionnaires will be arranged.

Please note that the data collected must be treated with due confidentiality and anonymity.

Yours sincerely

Buddy Govender
Senior manager: Information Services

ANNEXURE B: SAMPLE QUESTIONNAIRE

Department:					
Job Description	1	Town Planning Technician	2	Town Planning Technologist	
	3	Town Planning Proffesional	4	GIS Technician	
	5	GIS Technologist	6	GIS Proffesional	
	7	Other			
SECTION B: GIS					
How long have been using GIS *(please tick)*	1	0-1 years	2	1-5 years	3 More than 5 years
How often do you use GIS? *(please tick)*	1	Many times per day			
	2	Several times per week			
	3	Occasionally			
	4	Not often			
When using GIS, what do you mainly use it for? *(Please tick the most appropriate boxes)*	1	Point-and-click queries			
	2	Measurements			
	3	Data management			
	4	Creating maps from templates			
	5	Creating maps from scratch			
	6	Spatial Analysis			
	7	Editing Spatial data			
	8	Editing Attribute data			
	9	Other (Specify):			
Do you have a GIS qualification? *(Please tick)*	Yes	No			
If No, where did you learn to operate a GIS? *(please tick)*	1	At School			
	2	At the work-place			
	3	As part of different qualificatio			
	4	Short Courses			
	5	Other (Specify):			
Please indicate which of the following software you are co	1	ArcView 3.x			
	2	ArcGIS Desktop			
	3	ArcGIS Spatial Analyst			
	4	ArcGIS Online			
	5	ArcGIS Pro			
	5	Geomedia Intergraph			
	6	gvSIG			
	7	Quantum GIS			
	8	AutoCAD			
	9	MicroStation			
Please indicate which of the following software you have a	1	ArcView 3.x			
	2	ArcGIS Desktop			
	3	ArcGIS Spatial Analyst			
	4	ArcGIS Online			
	5	ArcGIS Pro			
	5	Geomedia Intergraph			
	6	gvSIG			
	7	Quantum GIS			
	8	AutoCAD			
	9	MicroStation			
Please indicate your opinion of your **institution's** GIS capacity *(please tick)*	1	Very good Skills, Data and Policies			
	2	Average Skills, Data and Policies			
	3	Poor Skills, Data and Policies			
Please indicate your opinion of your **department's** GIS capacity *(Please tick)*	1	Very good Skills, Data and Policies			
	2	Average Skills, Data and Policies			
	3	Poor Skills, Data and Policies			

SECTION C: ZONING		
How often do you use zoning data, maps and scheme docs. *(please tick)*	1	Many times per day
	2	Several times per week
	3	Occasionally
	4	Not often
When using zoning maps or data, What do you mainly use it for? *(please tick appropriate boxes)*	1	Queries by Property owners/ developers
	2	Queries by colleagues
	3	Vetting development applications
	4	Spatial and Statistical analysis
	5	Editing maps and Data
	6	I do not use Zoning data or maps
When using scheme regulation documents, What do you mainly use it for? *(Please tick appropriate boxes)*	1	Queries by Property owners/ developers
	2	Queries by colleagues
	3	Vetting development applications
	4	Checking As built-Compliance
	5	Informing strategic plans
	6	I do not use the regulations
Do you have a Town Planning qualification? *(Please tick)*	1	Yes
	2	No
If no, please specify how your job relates to zoning		
Please select the most appropriate definition of form-based coding	1	A system using predesigned forms for the updating of zoning files
	2	A zoning system concerned with the placement, shape and size of buildings
	3	A coding system designed for zoning within a GIS environment
Do you think form-based coding (or variations thereof) could be useful in the eThekwini area?	1	Yes
	2	No
SECTION D: GIS and ZONING		
Which of the following scheme regulations do you think could/ should be included in the GIS database? *(please tick the appropriate boxes)*	1	Coverage
	2	FAR
	3	Parking requirements
	4	Minimum lot size
	5	Height
	6	Setback lines
	7	Side Space
	8	Rear Space
	9	Build to lines
	10	Site Access points
Do you think it may be useful to represent regulations spatially?	1	Yes
	2	No
Do you think converting descriptive values such as FAR and Coverage to absolute values in the database would be	1	Yes
	2	No
Currently the regulations are not available in the GIS database. Please explain why you think they are not.		

ANNEXURE C: SAMPLE DATA COLLECTION FORM

Zone name										
Land Uses										
Permissable uses										
No. of Permissable Uses										
Uses with Special Conscent										
No. of Conscent Uses										
Prohibited Uses										
No. of Prohibited Uses										
Regulation 1: (Name)										
Type of Regulation	1-Nominal/ Descriptive									
	2-Ratio/ percentage									
	3-Absolute Value									
	4-Other (specifiy)									
Regulation Value	eg FAR=1.5									
Spatial Variation within Zone	1	Yes	2	No						
If Yes, specify geog. locations										
Can Regulation be represented in a GIS Database			1	Yes	2	No				
If No (12), Why?										
If Yes (12)	1	Spatial	2	Non-Spati	3	Both				
If Spatial (13), specify dimensionality/ Type		1	Point	2	Line	3	Polygon	4	Volume	
		5	Raster	6	Other					
Recommended Spatial Capture method		1	Digitize	2	Derive/ In	3	Survey	4	Scan	
		5	COGO	6	Other (Specify):					
Capture method requirements	Data	1	Parcels	2	Zoning	3	Both	4	Other	
	Formats	1	GIS	2	CAD	3	Both	4	Other	
	Process	1	Manual	2	Fully Auto	3	Semi-Auto			
	Skill level	1	Novice	2	Intermedi	3	Advanced			
Topological relationship with parcel		1	Within	2	Centroid Within		3	Contains		
		4	Near	5	Adjacent	6	Crosses	7	Crossed by	
		8	Are Identical		9	Share Line Segment				
Regulation Enforcement Type	1	Binary/ Hard	2	Fuzzy/ Soft						
If Fuzzy (), Model?	1	Vector (MR Buffers etc)		2	Raster (Distance, IDW etc)					
If Non-spatial (13), specify data type		1	Nominal	2	Ordinal	3	Ratio	4	Date	
		5	Cyclical	6	Interval					
Non-spatial Capture Approach		1	Manual	2	Automate	3	Semi-Auto			
Cardinality (with Parcel)	1	One-to-One	2	One-to-Many		3	Many-to-Many			
Regulation Enforcement Type	1	Binary/ Hard	2	Fuzzy /Soft						
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store						1	Yes	2	No	
If Yes, Data Type Recommendation		1	Ordinal	2	Interval	3	Date	4	Cyclical	
if Yes, Field parameters	Scale:			Precision:						
If Yes, recommended formula	$x =$									

Use this Regulation after DB for:	1	Mapping	1a	Single Symbols	2a	Unique Va	3a	Graduated maps		
	2	DB Queries								
	3	Spatial analysis								
	4	Statistical Analysis								
	5	Other								
Regulation 2: (Name)										
Type of Regulation	1-Nominal/ Descriptive									
	2-Ratio/ percentage									
	3-Absolute Value									
	4-Other (specifiy)									
Regulation Value	eg FAR=1.5									
Spatial Variation within Zone	1	Yes	2	No						
If Yes, specify geog. locations										
Can Regulation be represented in a GIS Database			1	Yes	2	No				
If No (12), Why?										
If Yes (12)	1	Spatial	2	Non-Spati	3	Both				
If Spatial (13), specify dimensionality/ Type		1	Point	2	Line	3	Polygon	4	Volume	
		5	Raster	6	Other					
Recommended Spatial Capture method		1	Digitize	2	Derive/ In	3	Survey	4	Scan	
		5	COGO	6	Other (Specify):					
Capture method requirements	Data	1	Parcels	2	Zoning	3	Both	4	Other	
	Formats	1	GIS	2	CAD	3	Both	4	Other	
	Process	1	Manual	2	Fully Auto	3	Semi-Auto			
	Skill level	1	Novice	2	Intermedi	3	Advanced			
Topological relationship with parcel		1	Within	2	Centroid Within		3	Contains		
		4	Near	5	Adjacent	6	Crosses	7	Crossed by	
		8	Are Identical		9	Share Line Segment				
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy/ Soft					
If Fuzzy (), Model?	1	Vector (MR Buffers etc)			2	Raster (Distance, IDW etc)				
If Non-spatial (13), specify data type		1	Nominal	2	Ordinal	3	Ratio	4	Date	
		5	Cyclical	6	Interval					
Non-spatial Capture Approach		1	Manual	2	Automate	3	Semi-Auto			
Cardinality (with Parcel)	1	One-to-One		2	One-to-Many		3	Many-to-Many		
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy /Soft					
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store						1	Yes	2	No	
If Yes, Data Type Recommendation		1	Ordinal	2	Interval	3	Date	4	Cyclical	
if Yes, Field parameters	Scale:			Precision:						
If Yes, recommended formula	$x =$									
Use this Regulation after DB for:	1	Mapping	1a	Single Symbols	2a	Unique Va	3a	Graduated maps		
	2	DB Queries								
	3	Spatial analysis								
	4	Statistical Analysis								
	5	Other								
Regulation 3: (Name)										
Type of Regulation	1-Nominal/ Descriptive									
	2-Ratio/ percentage									
	3-Absolute Value									
	4-Other (specifiy)									
Regulation Value	eg FAR=1.5									
Spatial Variation within Zone	1	Yes	2	No						
If Yes, specify geog. locations										
Can Regulation be represented in a GIS Database			1	Yes	2	No				

If No (12), Why?										
If Yes (12)	1	Spatial	2	Non-Spati	3	Both				
If Spatial (13), specify dimensionality/ Type		1	Point	2	Line	3	Polygon	4	Volume	
		5	Raster	6	Other					
Recommended Spatial Capture method		1	Digitize	2	Derive/ In	3	Survey	4	Scan	
		5	COGO	6	Other (Specify):					
Capture method requirements	Data	1	Parcels	2	Zoning	3	Both	4	Other	
	Formats	1	GIS	2	CAD	3	Both	4	Other	
	Process	1	Manual	2	Fully Auto	3	Semi-Auto			
	Skill level	1	Novice	2	Intermedi	3	Advanced			
Topological relationship with parcel		1	Within	2	Centroid Within		3	Contains		
		4	Near	5	Adjacent	6	Crosses	7	Crossed by	
		8	Are Identical		9	Share Line Segment				
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy/ Soft					
If Fuzzy (), Model?	1	Vector (MR Buffers etc)		2	Raster (Distance, IDW etc)					
If Non-spatial (13), specify data type		1	Nominal	2	Ordinal	3	Ratio	4	Date	
		5	Cyclical	6	Interval					
Non-spatial Capture Approach		1	Manual	2	Automate	3	Semi-Auto			
Cardinality (with Parcel)	1	One-to-One		2	One-to-Many		3	Many-to-Many		
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy /Soft					
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store						1	Yes	2	No	
If Yes, Data Type Recommendation		1	Ordinal	2	Interval	3	Date	4	Cyclical	
if Yes, Field parameters	Scale:			Precision:						
If Yes, recommended formula	$x =$									
Use this Regulation after DB for:	1	Mapping	1a	Single Symbols	2a	Unique Va	3a	Graduated maps		
	2	DB Queries								
	3	Spatial analysis								
	4	Statistical Analysis								
	5	Other								
Regulation 4: (Name)										
Type of Regulation	1-Nominal/ Descriptive									
	2-Ratio/ percentage									
	3-Absolute Value									
	4-Other (specifiy)									
Regulation Value	eg FAR=1.5									
Spatial Variation within Zone	1	Yes	2	No						
If Yes, specify geog. locations										
Can Regulation be represented in a GIS Database			1	Yes	2	No				
If No (12), Why?										
If Yes (12)	1	Spatial	2	Non-Spati	3	Both				
If Spatial (13), specify dimensionality/ Type		1	Point	2	Line	3	Polygon	4	Volume	
		5	Raster	6	Other					
Recommended Spatial Capture method		1	Digitize	2	Derive/ In	3	Survey	4	Scan	
		5	COGO	6	Other (Specify):					
Capture method requirements	Data	1	Parcels	2	Zoning	3	Both	4	Other	
	Formats	1	GIS	2	CAD	3	Both	4	Other	
	Process	1	Manual	2	Fully Auto	3	Semi-Auto			
	Skill level	1	Novice	2	Intermedi	3	Advanced			
Topological relationship with parcel		1	Within	2	Centroid Within		3	Contains		
		4	Near	5	Adjacent	6	Crosses	7	Crossed by	
		8	Are Identical		9	Share Line Segment				
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy/ Soft					
If Fuzzy (), Model?	1	Vector (MR Buffers etc)		2	Raster (Distance, IDW etc)					
If Non-spatial (13), specify data type		1	Nominal	2	Ordinal	3	Ratio	4	Date	
		5	Cyclical	6	Interval					
Non-spatial Capture Approach		1	Manual	2	Automate	3	Semi-Auto			
Cardinality (with Parcel)	1	One-to-One		2	One-to-Many		3	Many-to-Many		
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy /Soft					
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store						1	Yes	2	No	
If Yes, Data Type Recommendation		1	Ordinal	2	Interval	3	Date	4	Cyclical	

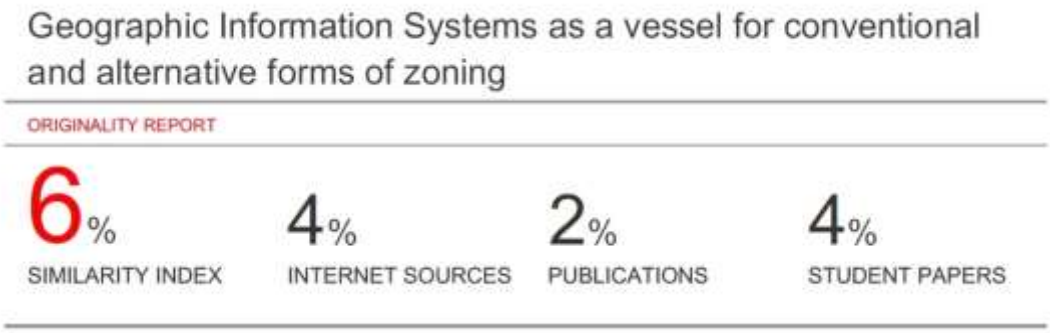
if Yes, Field parameters	Scale:				Precision:							
If Yes, recommended formula												
Use this Regulation after DB for:	1	Mapping	1a		Single Symbols		2a		Unique Va	3a		Graduated maps
	2	DB Queries										
	3	Spatial analysis										
	4	Statistical Analysis										
	5	Other										
Regulation 5: (Name)												
Type of Regulation	1-Nominal/ Descriptive											
	2-Ratio/ percentage											
	3-Absolute Value											
	4-Other (specifiy)											
Regulation Value	eg FAR=1.5											
Spatial Variation within Zone	1	Yes	2	No								
If Yes, specify geog. locations												
Can Regulation be represented in a GIS Database			1	Yes	2	No						
If No (12), Why?												
If Yes (12)	1	Spatial	2	Non-Spati	3	Both						
		1	Point	2	Line	3	Polygon	4	Volume			
If Spatial (13), specify dimensionality/ Type		5	Raster	6	Other							
		1	Digitize	2	Derive/ In	3	Survey	4	Scan			
Recommended Spatial Capture method		5	COGO	6	Other (Specify):							
	Data	1	Parcels	2	Zoning	3	Both	4	Other			
	Formats	1	GIS	2	CAD	3	Both	4	Other			
	Process	1	Manual	2	Fully Auto	3	Semi-Auto					
Capture method requirements	Skill level	1	Novice	2	Intermedi	3	Advanced					
		1	Within	2	Centroid Within		3	Contains				
		4	Near	5	Adjacent	6	Crosses	7	Crossed by			
Topological relationship with parcel		8	Are Identical		9	Share Line Segment						
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy/ Soft							
If Fuzzy (), Model?	1	Vector (MR Buffers etc)			2	Raster (Distance, IDW etc)						
		1	Nominal	2	Ordinal	3	Ratio	4	Date			
If Non-spatial (13), specify data type		5	Cyclical	6	Interval							
Non-spatial Capture Approach		1	Manual	2	Automate	3	Semi-Auto					
Cardinality (with Parcel)	1	One-to-One		2	One-to-Many		3	Many-to-Many				
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy /Soft							
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store						1	Yes	2	No			
If Yes, Data Type Recommendation		1	Ordinal	2	Interval	3	Date	4	Cyclical			
if Yes, Field parameters	Scale:				Precision:							
If Yes, recommended formula												
Use this Regulation after DB for:	1	Mapping	1a		Single Symbols		2a		Unique Va	3a		Graduated maps
	2	DB Queries										
	3	Spatial analysis										
	4	Statistical Analysis										
	5	Other										
Regulation 6: (Name)												
Type of Regulation	1-Nominal/ Descriptive											
	2-Ratio/ percentage											
	3-Absolute Value											
	4-Other (specifiy)											
Regulation Value	eg FAR=1.5											
Spatial Variation within Zone	1	Yes	2	No								
If Yes, specify geog. locations												
Can Regulation be represented in a GIS Database			1	Yes	2	No						

If No (12), Why?										
If Yes (12)	1	Spatial	2	Non-Spati	3	Both				
If Spatial (13), specify dimensionality/ Type		1	Point	2	Line	3	Polygon	4	Volume	
		5	Raster	6	Other					
Recommended Spatial Capture method		1	Digitize	2	Derive/ In	3	Survey	4	Scan	
		5	COGO	6	Other (Specify):					
Capture method requirements	Data	1	Parcels	2	Zoning	3	Both	4	Other	
	Formats	1	GIS	2	CAD	3	Both	4	Other	
	Process	1	Manual	2	Fully Auto	3	Semi-Auto			
	Skill level	1	Novice	2	Intermedi	3	Advanced			
Topological relationship with parcel		1	Within	2	Centroid Within		3	Contains		
		4	Near	5	Adjacent	6	Crosses	7	Crossed by	
		8	Are Identical		9	Share Line Segment				
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy/ Soft					
If Fuzzy (), Model?	1	Vector (MR Buffers etc)			2	Raster (Distance, IDW etc)				
If Non-spatial (13), specify data type		1	Nominal	2	Ordinal	3	Ratio	4	Date	
		5	Cyclical	6	Interval					
Non-spatial Capture Approach		1	Manual	2	Automate	3	Semi-Auto			
Cardinality (with Parcel)	1	One-to-One		2	One-to-Many		3	Many-to-Many		
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy /Soft					
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store						1	Yes	2	No	
If Yes, Data Type Recommendation		1	Ordinal	2	Interval	3	Date	4	Cyclical	
if Yes, Field parameters	Scale:			Precision:						
If Yes, recommended formula	$x =$									
Use this Regulation after DB for:	1	Mapping	1a	Single Symbols	2a	Unique Va	3a	Graduated maps		
	2	DB Queries								
	3	Spatial analysis								
	4	Statistical Analysis								
	5	Other								
Regulation 7: (Name)										
Type of Regulation	1-Nominal/ Descriptive									
	2-Ratio/ percentage									
	3-Absolute Value									
	4-Other (specifiy)									
Regulation Value	eg FAR=1.5									
Spatial Variation within Zone	1	Yes	2	No						
If Yes, specify geog. locations										
Can Regulation be represented in a GIS Database			1	Yes	2	No				
If No (12), Why?										
If Yes (12)	1	Spatial	2	Non-Spati	3	Both				
If Spatial (13), specify dimensionality/ Type		1	Point	2	Line	3	Polygon	4	Volume	
		5	Raster	6	Other					
Recommended Spatial Capture method		1	Digitize	2	Derive/ In	3	Survey	4	Scan	
		5	COGO	6	Other (Specify):					
Capture method requirements	Data	1	Parcels	2	Zoning	3	Both	4	Other	
	Formats	1	GIS	2	CAD	3	Both	4	Other	
	Process	1	Manual	2	Fully Auto	3	Semi-Auto			
	Skill level	1	Novice	2	Intermedi	3	Advanced			
Topological relationship with parcel		1	Within	2	Centroid Within		3	Contains		
		4	Near	5	Adjacent	6	Crosses	7	Crossed by	
		8	Are Identical		9	Share Line Segment				
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy/ Soft					
If Fuzzy (), Model?	1	Vector (MR Buffers etc)			2	Raster (Distance, IDW etc)				
If Non-spatial (13), specify data type		1	Nominal	2	Ordinal	3	Ratio	4	Date	
		5	Cyclical	6	Interval					
Non-spatial Capture Approach		1	Manual	2	Automate	3	Semi-Auto			
Cardinality (with Parcel)	1	One-to-One		2	One-to-Many		3	Many-to-Many		
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy /Soft					
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store						1	Yes	2	No	

If Yes, Data Type Recommendation			1	Ordinal	2	Interval	3	Date	4	Cyclical		
if Yes, Field parameters	Scale:				Precision:							
If Yes, recommended formula												
Use this Regulation after DB for:		1	Mapping	1a	Single Symbols		2a	Unique Va	3a	Graduated maps		
		2	DB Queries									
		3	Spatial analysis									
		4	Statistical Analysis									
		5	Other									
Regulation 8: (Name)												
Type of Regulation	1-Nominal/ Descriptive											
	2-Ratio/ percentage											
	3-Absolute Value											
	4-Other (specifiy)											
Regulation Value					eg FAR=1.5							
Spatial Variation within Zone		1	Yes	2	No							
If Yes, specify geog. locations												
Can Regulation be represented in a GIS Database				1	Yes	2	No					
If No (12), Why?												
If Yes (12)		1	Spatial	2	Non-Spati	3	Both					
If Spatial (13), specify dimensionality/ Type			1	Point	2	Line	3	Polygon	4	Volume		
			5	Raster	6	Other						
Recommended Spatial Capture method			1	Digitize	2	Derive/ In	3	Survey	4	Scan		
			5	COGO	6	Other (Specify):						
Capture method requirements	Data		1	Parcels	2	Zoning	3	Both	4	Other		
	Formats		1	GIS	2	CAD	3	Both	4	Other		
	Process		1	Manual	2	Fully Auto	3	Semi-Auto				
	Skill level		1	Novice	2	Intermedi	3	Advanced				
Topological relationship with parcel			1	Within	2	Centroid Within		3	Contains			
			4	Near	5	Adjacent	6	Crosses	7	Crossed by		
			8	Are Identical		9	Share Line Segment					
Regulation Enforcement Type		1	Binary/ Hard		2	Fuzzy/ Soft						
If Fuzzy (), Model?		1	Vector (MR Buffers etc)			2	Raster (Distance, IDW etc)					
If Non-spatial (13), specify data type			1	Nominal	2	Ordinal	3	Ratio	4	Date		
			5	Cyclical	6	Interval						
Non-spatial Capture Approach			1	Manual	2	Automate	3	Semi-Auto				
Cardinality (with Parcel)		1	One-to-One		2	One-to-Many		3	Many-to-Many			
Regulation Enforcement Type		1	Binary/ Hard		2	Fuzzy /Soft						
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store							1	Yes	2	No		
If Yes, Data Type Recommendation			1	Ordinal	2	Interval	3	Date	4	Cyclical		
if Yes, Field parameters	Scale:				Precision:							
If Yes, recommended formula												
Use this Regulation after DB for:		1	Mapping	1a	Single Symbols		2a	Unique Va	3a	Graduated maps		
		2	DB Queries									
		3	Spatial analysis									
		4	Statistical Analysis									
		5	Other									
Regulation 9: (Name)												
Type of Regulation	1-Nominal/ Descriptive											
	2-Ratio/ percentage											
	3-Absolute Value											
	4-Other (specifiy)											
Regulation Value					eg FAR=1.5							
Spatial Variation within Zone		1	Yes	2	No							
If Yes, specify geog. locations												

Can Regulation be represented in a GIS Database		1	Yes	2	No				
If No (12), Why?									
If Yes (12)	1	Spatial	2	Non-Spati	3	Both			
If Spatial (13), specify dimensionality/ Type		1	Point	2	Line	3	Polygon	4	Volume
		5	Raster	6	Other				
Recommended Spatial Capture method		1	Digitize	2	Derive/ In	3	Survey	4	Scan
		5	COGO	6	Other (Specify):				
Capture method requirements	Data	1	Parcels	2	Zoning	3	Both	4	Other
	Formats	1	GIS	2	CAD	3	Both	4	Other
	Process	1	Manual	2	Fully Auto	3	Semi-Auto		
	Skill level	1	Novice	2	Intermedi	3	Advanced		
Topological relationship with parcel		1	Within	2	Centroid Within		3	Contains	
		4	Near	5	Adjacent	6	Crosses	7	Crossed by
		8	Are Identical		9	Share Line Segment			
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy/ Soft				
If Fuzzy (), Model?	1	Vector (MR Buffers etc)			2	Raster (Distance, IDW etc)			
If Non-spatial (13), specify data type		1	Nominal	2	Ordinal	3	Ratio	4	Date
		5	Cyclical	6	Interval				
Non-spatial Capture Approach		1	Manual	2	Automate	3	Semi-Auto		
Cardinality (with Parcel)	1	One-to-One		2	One-to-Many		3	Many-to-Many	
Regulation Enforcement Type	1	Binary/ Hard		2	Fuzzy /Soft				
If Non-spatial AND DataType is Ratio/ Interval, can value be converted to Absolute and Store						1	Yes	2	No
If Yes, Data Type Recommendation		1	Ordinal	2	Interval	3	Date	4	Cyclical
if Yes, Field parameters	Scale:			Precision:					
If Yes, recommended formula					$x =$				
Use this Regulation after DB for:	1	Mapping	1a	Single Symbols		2a	Unique Va	3a	Graduated maps
	2	DB Queries							
	3	Spatial analysis							
	4	Statistical Analysis							
	5	Other							

ANNEXURE D: SIMILIARITY INDEX



Full report as attached PDF file.